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NASA CR-112,226

USER'S MANUAL

BUCLASP 2

A COMPUTER PROGRAM FOR INSTABILITY ANALYSIS OF BIAXIALLY LOADED COMPOSITE STIFFENED PANELS AND OTHER STRUCTURES

by

L. L. Tripp, M. Tamekuni, and A. V. Viswanathan

MARCH 1973

Prepared under Contract NAS 1-8858

by

BOEING COMMERCIAL AIRPLANE COMPANY

Seattle Washington

for

LANGLEY RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

This work was sponsored by the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia under Contract Number NAS1-8858, Phase III.

The work was done under the direction of program manager Dr. Ralph E. Miller, Jr. of The Boeing Company and technical monitor Dr. Michael F. Card of NASA.

ABSTRACT

This manual describes the use of the computer program BUCLASP2. The program is intended for linear instability analyses of structures such as unidirectionally stiffened panels. Any structure that has a constant cross section in one direction, that may be idealized as an assemblage of beam elements and laminated flat and curved plate strip elements can be analyzed. The loadings considered are combinations of axial compressive loads and in-plane transverse loads. The two parallel ends of the panel must be simply supported and arbitrary elastic boundary conditions may be imposed along any one or both external longitudinal side.

This manual consists of instructions for use of the program with sample problems, including input and output information. The theoretical basis of BUCLASP2 and correlations of calculated results with known solutions, are presented in Reference 1.

KEY WORD LIST

STRUCTURE	COMPOSITE PLATES, FLAT AND CURVED
BUCKLING	COMPOSITE BEAMS
STIFFENED PANELS	BIAXIAL LOADING

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1.0 SCOPE OF BUCLASP2

The computer program BUCLASP2 is designed to perform instability analyses for structures such as unidirectionally-stiffened, rectangular composite panels. The structure is idealized as an assemblage of beam elements laminated curved plate strip elements and laminated flat plate strip elements. Each element extends the full length of the structure. The element edges which are normal to the longitudinal axis of the panel are assumed to be simply supported and any external edge parallel to the longitudinal axis may be arbitrarily constrained by specifying the appropriate spring constants. Plate offsets can be employed when needed to correctly idealize a structure.

The analysis is based on linear, elastic theory with prebuckling stresses and deformations ignored. Stress analyses cannot be performed by using BUCLASP2. The loadings considered are special combinations of constant in-plane axial and transverse loads and strains.

The individual load dependent elemental stiffnesses are solved exactly and then appropriately merged to form the total stiffness matrix of the structure. Inter-element equilibrium and displacement compatibility conditions are automatically satisfied. By setting the determinant of the load dependent total stiffness matrix to zero, a nonlinear eigenvalue problem is created. An iterative scheme, based on successive guesses of the loads, is then used to extract the minimum eigenvalue. In order to keep the number of guesses to a minimum, the method described in Reference 1 is used.

The critical loads are solved for each specified axial wave number, m, and mode shape calculations are made only for the m value that corresponds to the lowest critical load. In order to get the lowest buckling load, the structure should be analyzed for different m values and a search made to find the lowest critical load of the structure.

2.0 BASIC INFORMATION

This section presents the basic information required by BUCLASP2 users for performing buckling analyses. Figure 2.1 shows the cross section of an arbitrary structure. The circled numbers are element numbers. Extremities of each plate element and the shear centers of each beam element are indicated by dots. The dashed line is drawn through the mid-planes of each plate element.

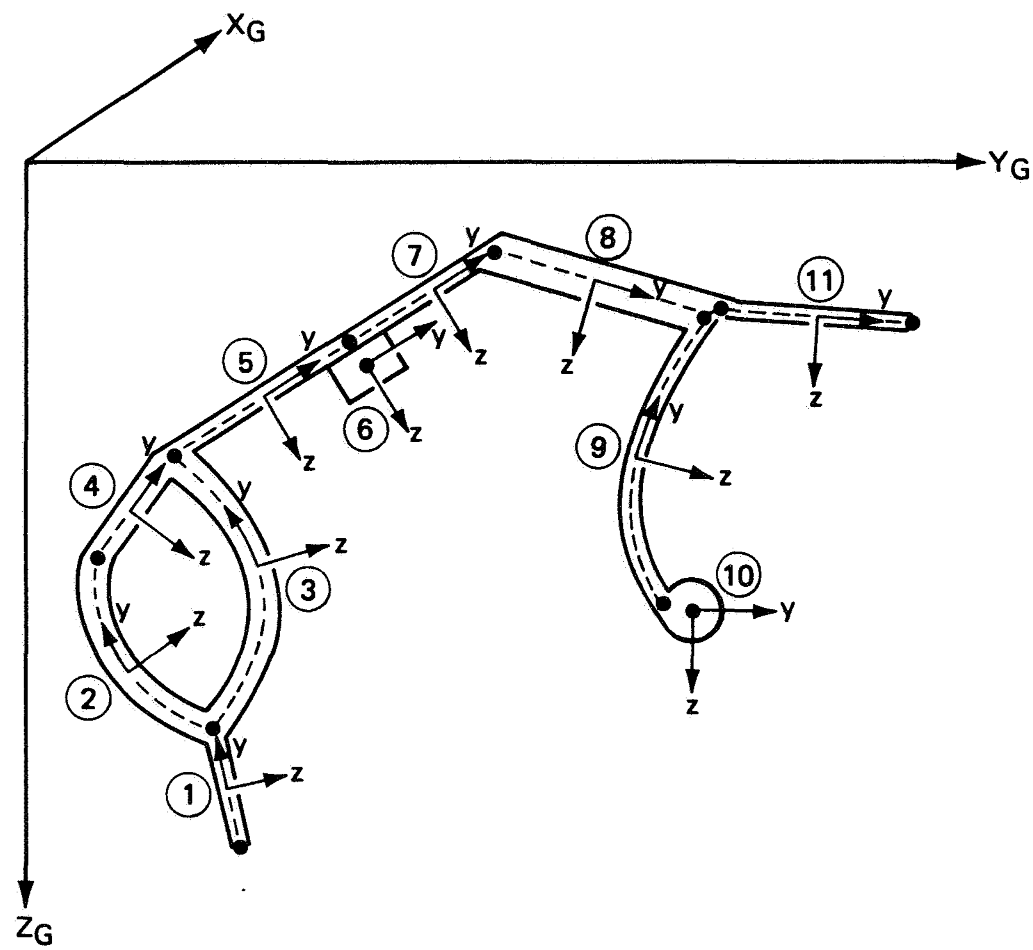


Figure 2.1 Idealization of an Arbitrary Structure

2.1 Geometry

2.1.1 Coordinate Systems

All structural geometries are defined relative a global (overall) right-handed rectangular Cartesian coordinate system. The axes of this triad are denoted by X_G, Y_G, and Z_G in Figure 2.1. The longitudinal axis of the structure is in the same direction as X_G. Local element coordinate systems will be discussed individually for each element in Section 2.2.

2.1.2 Nodes

The dots shown in the Figure 2.1 will be referred to as nodes. They are actually lines that are parallel to X_G. A node is identified by its coordinates in the global system and by its user-assigned node number. This node number is only for the user's convenience since the program automatically numbers the nodes sequentially according to the input order. The first input node will be internal node number 1, the second input node, 2, etc. Generally, the user node numbers will not be the same as the internal node number. No reordering of nodes is done internally.

2.2 Elements

There are three basic types of elements: (1) flat plate, (2) curved plate, and (3) beam elements. All elements extend the full length of the structure. A plate element is defined by a pair of node numbers that corresponds to the sides of the element. In Figure 2.2 the plate element is defined by nodes A and B. A beam element is defined by a node that corresponds to the beam shear center. In Figure 2.1 the following observations can be made:

(a) 1 , 4 , 5 , 7 , 8 and 11 are flat plate elements.
(b) 2 , 3 and 9 are curved plate elements.
(c) 6 and 10 are beam elements.

2.2.1 Plate Elements

There are two types of plate elements, flat and curved. The following discussion applies to both types except when reference is made to a particular type of plate element:

Local Coordinate System

The local coordinate system of a plate element is defined by the ordering of the node numbers that identify the element. The local y axis of the plate element is in the direction from the first node of the element to its second node. For example in Figure 2.2 the element is defined from node A to node B, and the resulting direction of the local y axis of the element is as shown. The local y axis of the curved plate element is along the arc from A to B. The local x axis is parallel to and in the same direction as X_G. The local z axis is determined by the right-hand rule. The origin of the local axis is on the mid-surface of the element and midway between its nodes.

Properties

In its most general form, the plate element can be multi-layered, each layer being orthotropic with respect to the local plate axes. In its simplest form, the element degenerates to a single isotropic layer. The thickness of each layer is assumed to be constant. The user must specify the thickness and material property of each layer.

The first lamina of a laminated plate element is defined as the external layer in the negative z direction. The last lamina is the extreme layer in the positive z direction (see Figure 2.2). It is important that the layers are input in this particular order.

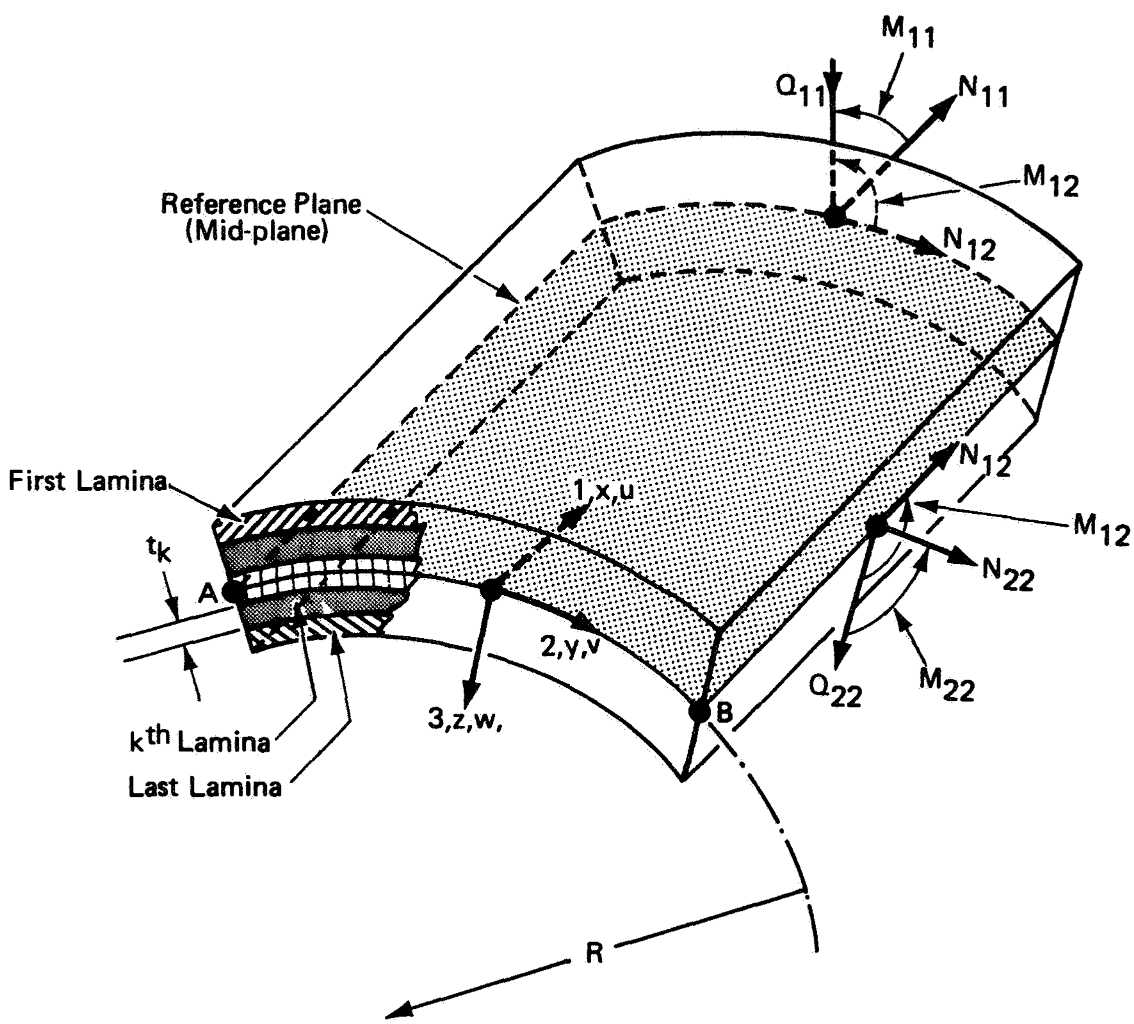


Figure 2.2 Laminated Plate Element

Radius of Curvature of Curved Plate

The curved plate element is actually a strip of a circular cylindrical shell. Therefore, only one radius of curvature, R, need be defined for this element. The sign convention for R is defined in the following manner: R is positive if the vector from the element to the center of curvature is in the same direction as the local z axis of the element. The magnitude of R is measured from the mid-surface of the element to the center of curvature. In Figure 2.3 the sign of R for elements a and b is negative, whereas it is positive for element c.

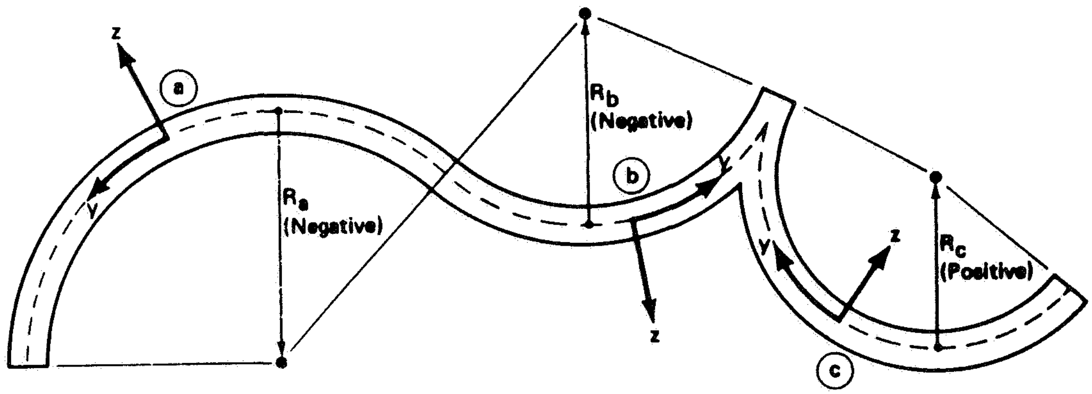


Figure 2.3 Curved Plate Elements

2.2.2 Beam Elements

There are two basic types of beam elements that are available in BUCLASP2. They are the laminated beam elements, circular and rectangular in cross section, and the general beam element. The local x axes of all beam elements are directed in the same direction as the global X_G axis and parallel to it.

Laminated Beams

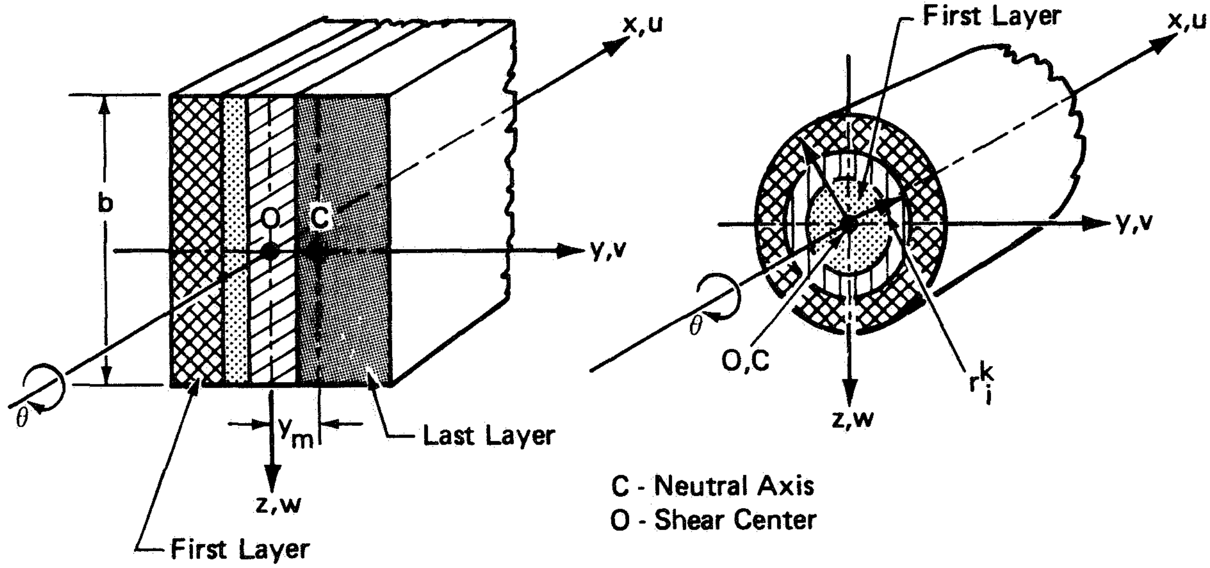
Rectangular:

The rectangular laminated beam is shown in Figure 2.4(a). The depth of each layer is b. The origin of the local axis system is taken at the shear center, 0, of the beam. The local y axis of this element could either be in the direction as shown in Figure 2.4(a) or in the opposite direction. The local z axis is determined by using the right-hand rule.

The laminae are ordered sequentially in the direction of the local y axis as indicated by Figure 2.4(a). Thus, if the local y axis were in the opposite direction, the ordering of the layers would be reversed.

Circular:

The beam is laminated in the manner shown in Figure 2.4(b). The first layer is the innermost layer and the ordering of the layers extends outward. The local y axis of this element can be in any direction in the plane of the beam cross section. The local z axis is again determined by the right-hand rule.



(a) Laminated Rectangular Beam

(b) Laminated Circular Beam

Figure 2.4 Laminated Beam Elements

General Beam Element:

The local y axis of the element can be in any direction in the plane of the beam cross section. The local z axis is defined by the right-hand rule. Properties such as inertias, areas, torsion constants and warping constants are input with respect to the local coordinate system. The orientation of a beam element is defined relative to the global coordinate system by specifying the angle between the global and local axes.

2.3 Plate Offsets

The element stiffnesses are originally defined at the element "local nodes". A plate element has two "local nodes" defined as the longitudinal edges lying in the mid-surface and the "local node" for a beam element is defined by its shear center. When two or more elements are joined together, the appropriate element stiffnesses can be merged at the juncture if the "local nodes" of all elements are coincident at the juncture. If the "local nodes" at this juncture are not coincident, it is necessary to define a common node where all the element stiffnesses can be merged properly. By necessity this common node must be a user input node. By using plate offsets, the user effectively defines the element stiffness at some node other than the plate "local node", thereby, giving him a tool to meet the above requirements. This non-"local node" is referred to as an "offset node". It must, however, be one of the user-defined nodes.

A plate with offsets can be interpreted as a pseudo plate element with a "link" connecting one of the plate "local nodes" to an "offset node". This link allows the element stiffness at a "local node" to be transferred to an "offset node".

There is no offset capability for the beam element in this program. This, however, is not detrimental since in all cases plate offsets can be used to idealize non-coincident junctures.

A situation where plate offsets can be used is when the mid-surfaces of plates do not intersect at the juncture. Offsets can also be used when the shear center of a beam does not coincide with the mid-surface of an adjoining plate.

The plate offset is a vector which is specified by two components, y_0 and z_0 from the edge of the plate element (see Figure 2.5.1 and 2.5.2). The y_0 and z_0 vector components are measured relative to the local y and z axis respectively. They are positive when their directions coincide with the positive directions of the local axes. z_0 is measured from the negative-z plate surface (exterior surface in the negative-z direction) and y_0 is measured from the plate "local node". It must be emphasized that z_0 is not measured from the "local node".

Figure 2.5.1 illustrates the cross section of a panel in which two plate elements intersect a beam element. The input nodes coincide with the plate "local nodes" but they are not coincident with the beam shear center. Since these nodes are not coincident at the juncture and a beam offset capability is not available, offsets for plate elements 1 and 3 must be specified. Consequently, the element stiffnesses will be merged at 3, the beam node.

Figure 2.5.2 illustrates two examples where plate elements of unequal thicknesses meet. In the top figure, the mid-surfaces of plate elements 1 and 3 with equal thicknesses passes through the input nodes. Element 2 , however, is a two-layered plate with a different thickness. Since the stiffness for element 2 is formulated relative to its "local nodes", offsets must be defined to transfer this stiffness to nodes 2 and 3 to ensure the desired structural integrity. If offsets were not specified for this example, the true configuration of this structure would not be retained in the analysis. That is, element 2 would be situated such that its mid-surface coincides with the mid-surfaces of 1 and 3.

It should be noted that z_0 is not the offset distance from a plate "local node" to the "offset node". This offset component, however, is used by the program to formulate the actual offset-transfer of the

stiffness. For example, the stiffness at the mid-surface of 2 in Figure 2.5.2, is transferred to nodes 2 and 3 based on the z_0 offset indicated therein.

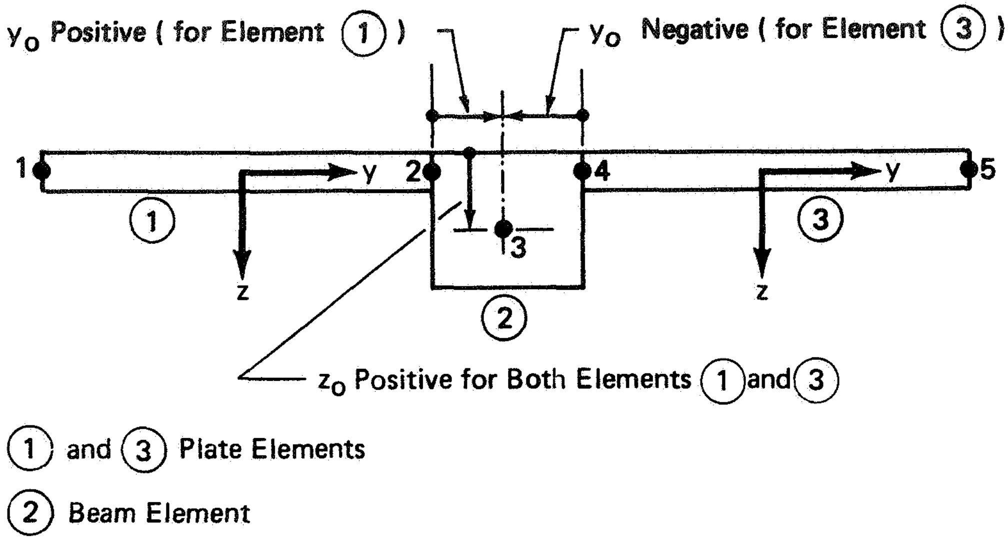


Figure 2.5.1 Offsets in Presence of Beams

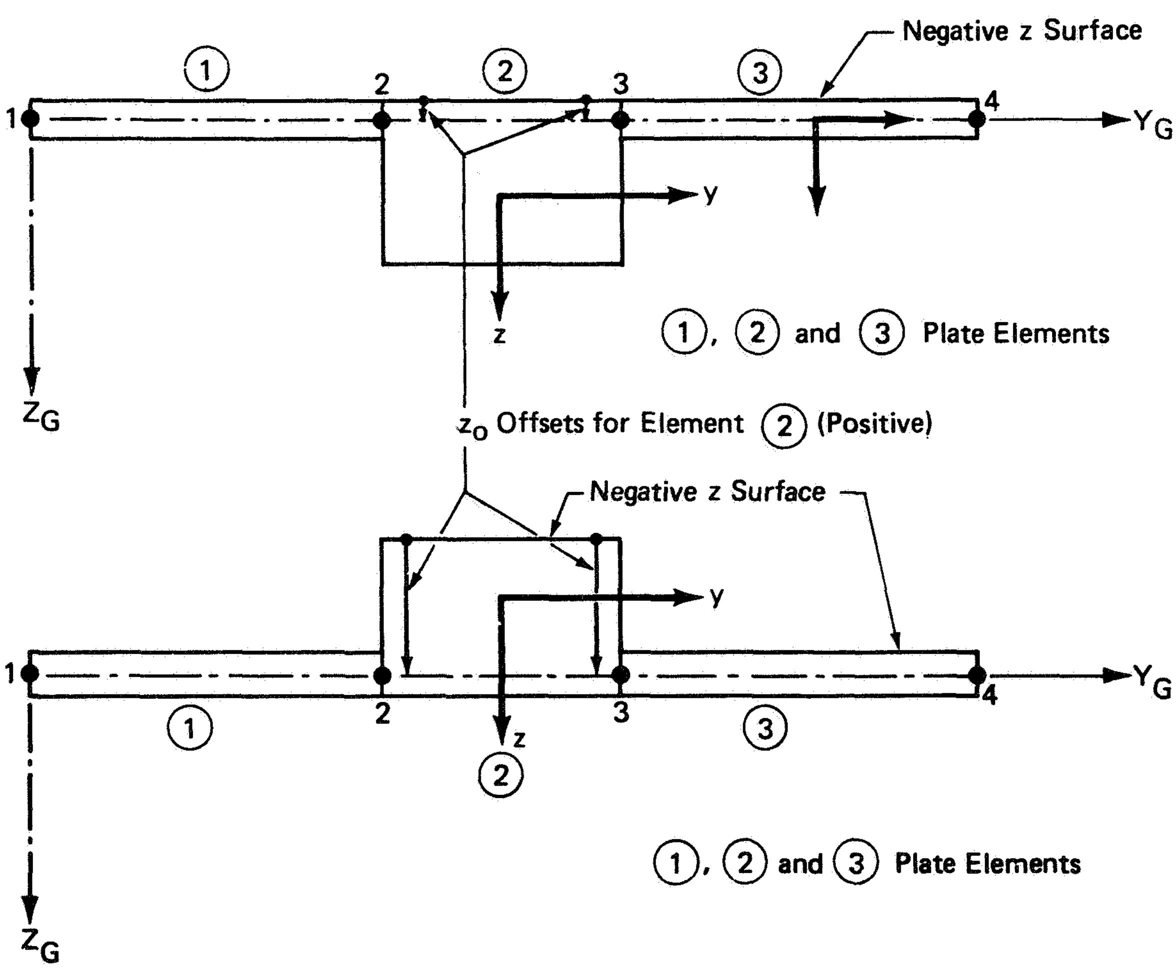


Figure 2.5.2 Plate Offsets

2.4 Boundary Conditions

An external side (parallel to the X_G axis) of a plate element may be constrained by specifying the following boundary conditions:

(a) Simply supported

$$w = M_{22} = N_{22} = u = 0$$

(b) Clamped

$$w = \theta = N_{22} = u = 0$$

(c) Free

$$Q = M_{22} = N_{22} = N_{12} = 0$$

(d) Sprung

The constrained or sprung degrees of freedoms are defined with respect to the local coordinate system of the plate element. Boundary conditions cannot be applied to a beam element node or an internal node. For a sprung node of a plate element, the spring stiffnesses for all four degrees of freedom must be specified. To delete or constrain a freedom, use a large value for the corresponding spring constant, e.g., 1×10^{100}.

2.5 Element Loadings

The distribution of the total buckling load to individual elements is discussed in this section. In all cases the inplane loads N_{11} and N_{22} for plate elements and axial load P_b for beam elements are uniform. Shear loads N_{12} and moments are not considered. "Affected" elements are herein defined as plate elements subjected to transverse N_{22} load. The N_{22} load is equal to zero for non-"affected" elements. All "affected" plate elements are subjected to the same N_{22} load.

Following are the special options that are available in the code. In the most general case, all options listed below can be used to solve buckling problems of biaxially loaded panels. For uniaxial buckling analysis, these options can be used by setting to zero, properly selected input parameters.

(1) Biaxial loading, constant specified N_{22} load

This option is to be used for a panel that is loaded by a constant side load. The side load N_{22} is applied to all "affected" elements. While preserving strain compatibility in the longitudinal direction, the critical N_{11} load is solved. If the input N_{22} load is specified as zero, the unixial buckling load of the panel will be computed. For a stiffened panel under biaxial loads, the stiffener webs and outstanding legs would normally not be subjected to the transverse N_{22} load, while the skin of the panel would be loaded in the transverse direction. For this panel, the skin elements would be "affected" and the stiffener webs and outstanding legs would be non-"affected".

(2) Biaxial loading, constant specified biaxial load ratio

The biaxial load ratio is defined as the N_{11} load of the <u>first</u> "affected" plate element divided by the N_{22} side load. While preserving longitudinal strain compatibility of all elements, including beams, and by keeping the biaxial load ratio constant, the critical buckling load is calculated.

(3) Biaxial loading, constant specified longitudinal strain

The specified longitudinal strain is the same for all elements in the panel and will remain constant. N_{22} critical load will be computed for this option. Only "affected" plate elements will be subjected to the N_{22} load.

(4) Biaxial loading, constant specified axial N_{11} load

The panel buckling load will be established for a constant total axial load. The N_{11} load for the <u>first</u> plate element is specified. Initially, by assuming longitudinal strain compatibility at zero N_{22} load, the N_{11} axial loads in all elements are found. These axial loads will remain constant. The N_{22} critical loads on "affected" elements will then be computed. At the buckling load, longitudinal strain compatibility will not necessarily be preserved. If N_{11} is specified as zero, the panel buckling load due to side load only will be calculated.

For the options listed above, all elements in the panel, beams and plates will be subjected to N_{11} loads, the exception being the case where the specified N_{11} load in option (4) is set equal to zero. Tensile transverse loads and strains can also be specified.

2.6 Substructures

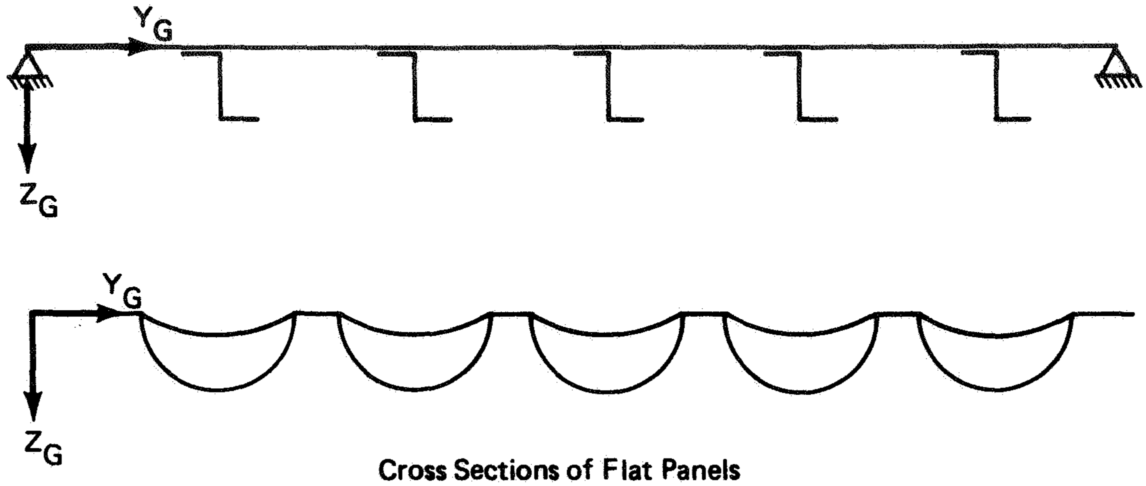
Three types of substructures are considered in BUCLASP2/ (1) start, (2) repeat and (3) end. The basic reason for including these types of substructures is to efficiently analyze panels with many repeated structural groups along the panel width. Examples of these types of panels are shown in Figure 2.6. The merged stiffness matrix for this type of panel consists of many repetitive submatrices because the repetitive substructures yield identical stiffnesses. BUCLASP2 takes advantage of this repetitiveness by dividing the stiffness matrix into three distinct blocks, one for each start, repeat and end substructure, and uses only one repeat block (corresponding to the repeat substructure) for the buckling load computations. Thus the generation and solution times for the stiffness matrix are reduced and the storage requirements are also alleviated.

The user may divide a panel, with or without repetitive structural groups, such that it consists of one start substructure, one, many, or no repeat substructures and one end substructure. Further, a panel may be idealized with the following combinations of substructures;

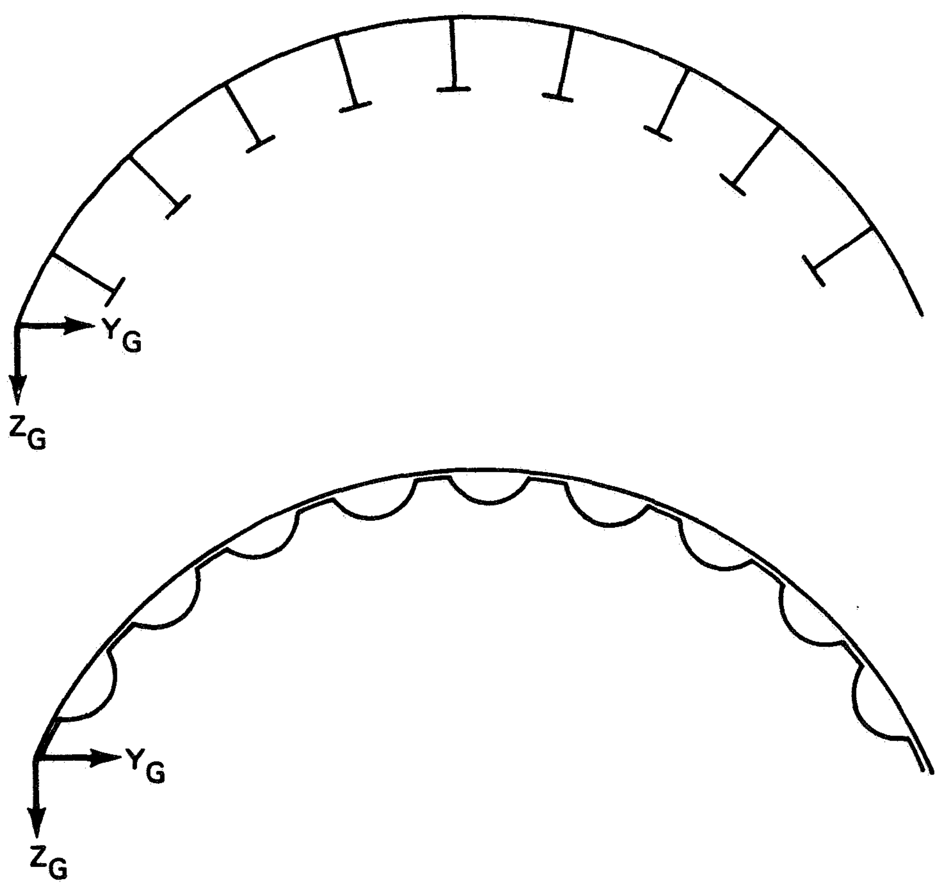
(1) start substructure only
(2) start and end substructures only
(3) start, repeat (one or more) and end substructures.

It should be obvious at this point that panels with no repeatable structural groups can have a maximum of one repeat substructure.

It is recommended that the start substructure be larger of the three substructures, for efficiency reasons in the determinant calculations.



Cross Sections of Flat Panels



Cross Sections of Curved Panels

Figure 2.6 Examples of Repeated Structures

2.6.1 Flat Panel with Repeated Substructures

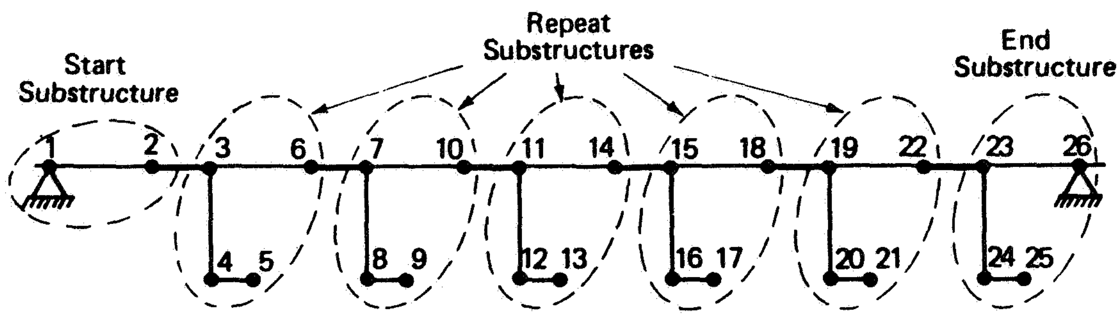
For a panel with repeated substructures, a reduced version of the actual panel may be specified for input. For example, see Figure 2.7. (a) is the actual panel and (b) is the reduced panel used for input. The nodal coordinates of 7 to 10 of (b) are input such that they model the end substructure of the actual panel, (a), as if it is moved to the left and attached to the first repeat substructure. Therefore, nodes 7 to 10 of the reduced panel, (b), are related to nodes 23 to 26 of (a), the actual panel. Consequently, nodes 11 to 22 of (a) are not directly included by coordinates in the input, but are implicitly specified through the repeat substructure.

After drawing a sketch of the actual structure, the user must identify the nodes that belong in the three different substructure types. For the start and end substructures, the only limitation is that there must be at least one interior node, a node without any specified boundary conditions, in each substructure. To ensure that the repeat substructure is accurately identified, the substructure corresponding nodes must be identified. The corresponding nodes are those node pairs at which the stiffnesses are identical. In other words, all elements meeting at corresponding nodes in all repeat substructures must be identical in all respects, including loadings and boundary conditions.

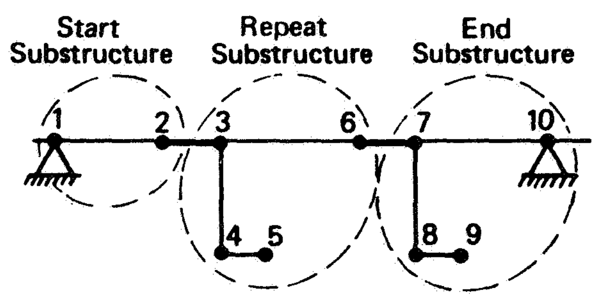
For the example from Figure 2.7 (a), inspection shows that nodes 7, 11, 15 and 19 are the corresponding nodes to node 3. Therefore, node 3 is a valid node for the repeat substructure. Similarly, node 6 is a valid node for the repeat substructure with nodes 10, 14, 18, 22 as correspondence nodes; node 4 with 8, 12, 16, 20; and node 5 with 9, 13, 17 and 21. One should note that node 23 is not a corresponding node of node 3 because the specified boundary condition at node 26 results in the stiffness contribution of element 23-26 to node 23 being unequal to the stiffness contribution of element 3-6 to node 3. Thus, node 23 may not be included in the repeat substructure.

From this user exercise one can conclude that, a) the substructure unit made up of nodes 3, 4, 5, 6 is a repeat substructure, and b) there are (5) repeat substructures.

Node 2 is included in the start substructure because boundary conditions are specified for node 1. The selection of nodes for the end substructure is obvious at this point.



(a) Zee Stiffened Panel - Actual



(b) Reduced Zee Siffened Panel

Figure 2.7 Examples of Repeat Substructures

2.6.2 Curved Panel with Repeated Substructures

For curved panels with repeatable substructures, repeatability of the nodes for the repeat substructure must be viewed in the curved panel cylindrical coordinate system which is shown in an example of Figure 2.8. R_p, θ and X_G are the axes of this coordinate system. The same guidelines as the ones discussed for flat panels are applicable for curved panels. The reduced structure for input is shown below the actual structure. As in flat panels, the end substructure is moved from its original position and is attached to the repeat substructure in the reduced version. The nodal coordinates are input in the global coordinate system (X_G, Y_G and Z_G) for the reduced structure.

$\Delta\theta$, the include angle, in Figure 2.8 is the angle measured from a point in a repeat substructure to its corresponding point in the next repeat substructure. The positive sign of $\Delta\theta$ is as shown. If the curved panel in Figure 2.8 is to be repeated from right to left instead of left to right as shown, the sign of $\Delta\theta$ would be negative. In terms of vectors, the positive rotation vector $\Delta\theta$ is parallel to and in the same direction as X_G using the right handed convention.

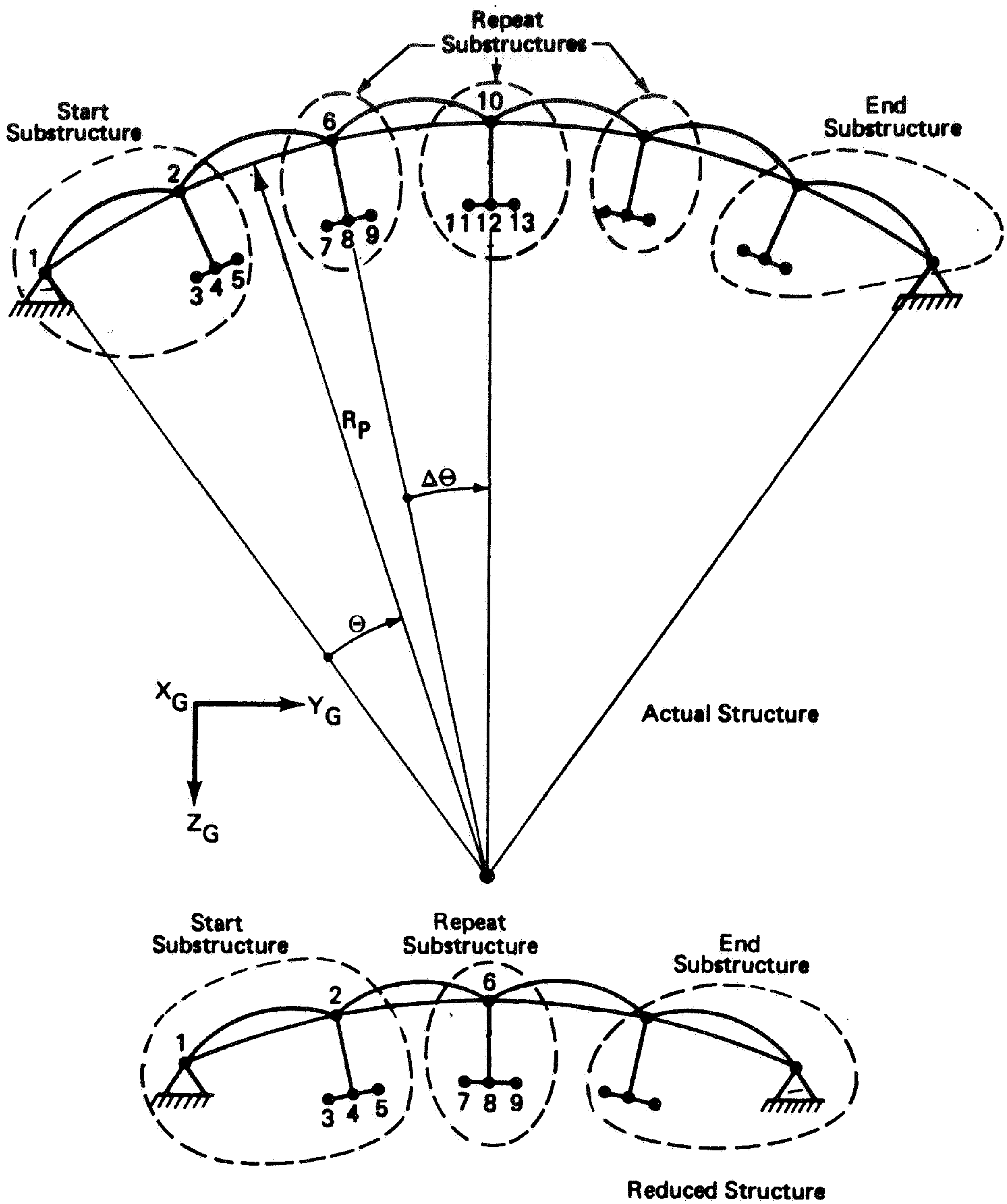


Figure 2.8 Curved Panel With Repeated Structure

2.6.3 Repeat Substructure Interrelationship Node Pairs

The mode shapes for elements of the panel (not the reduced structure) is provided by the program. These elemental mode shapes are derived from the relative displacements which were determined individually for each node of the actual panel (not just the reduced structure). The previous input information on repeat substructures was adequate to produce (internally) the total structure stiffness from the (input) reduced structure. However, additional information is required to identify elements that connect one repeat substructure to another repeat substructure for the purpose of calculating elemental mode shapes.

From the definition of a repeat substructure, any element, that connects the start substructure to the adjoining repeat substructure, has a corresponding element (topologically similar), that connects the repeat substructure to the end substructure. The requirement then becomes one of identifying;

(a) for each connecting element between the start and repeat substructures, the node that lies in the start substructure, and

(b) for each connecting element (topologically corresponding to (a)) between the repeat and end substructures, the node that lies in the repeat substructure.

The nodes indicated above become logically a node pair between corresponding elements and are defined as "interrelationship node pairs".

As an aid to the user, the following steps are recommended (see Figure 2.9).

(1) After encircling the nodes for different substructures as shown in Figure 2.9, identify all element(s) that connects the start substructure to the repeat substructure. (Elements 3 , 4 , 5 , 6 and 7 of Figure 2.9)

(2) Identify all element(s) connecting the repeat and end substructures. (Elements 13 , 14 , 15 , 16 and 17 of Figure 2.9)

(3) Pair all elements of (1) above, with corresponding elements (topologically similar) from (2) above. For the panel in Figure 2.9, the element pairs are: (3 , 13), (4 , 14), (5 , 15), (6 , 16) and (7 , 17).

(4) For each corresponding element pair, select the start start substructure node from element(s) of (1) above and the repeat substructure node from element(s) of (2) above. These two nodes constitute the interrelationship node pair. For element pair (3 , 13), they are nodes (1,7). Similarly, nodes (1,7) are the interrelationship node pair for element corresponding pair (4 , 14); nodes (2,8) for (5 , 15) and nodes (3,9) for (6 , 16) and (7 , 17). Note that for any interrelationship node pair, one node is from the start substructure and the other from the repeat substructure.

The table below for Figure 2.9 summarizes the recommended steps indicated above. The interrelationship node pairs are shown encircled.

Element	Start Substructure Node	Repeat Substructure Node	End Substructure Node
3	1	4	-
13	-	7	10
4	1	5	-
14	-	7	11
5	2	5	-
15	-	8	11
6	3	5	-
16	-	9	11
7	3	6	-
17	-	9	12

As an additional example, see Figure 2.7(b). Following the steps above, the interrelationship node pair is found to be (2,6) for the zee stiffened panel.

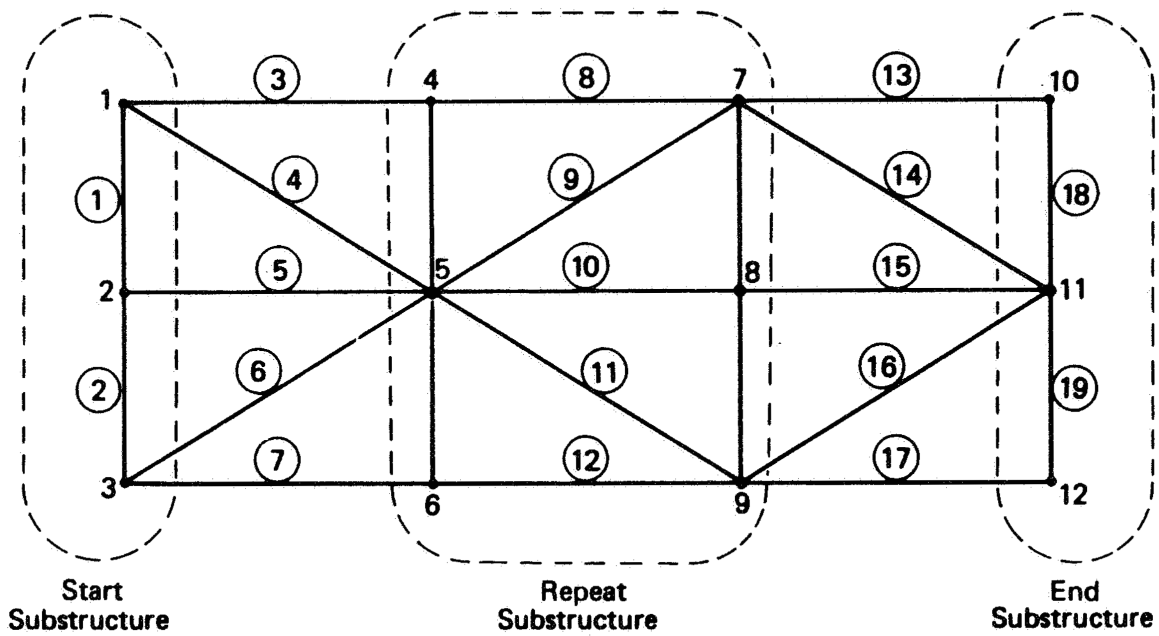
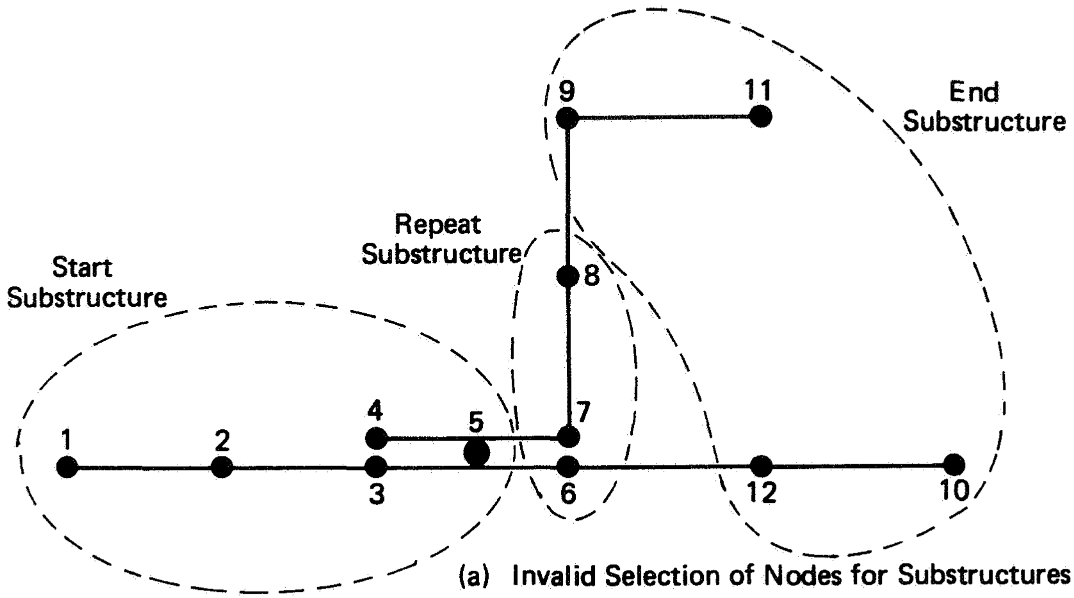


Figure 2.9 Example for Repeat Substructure Interrelationship Node Pairs

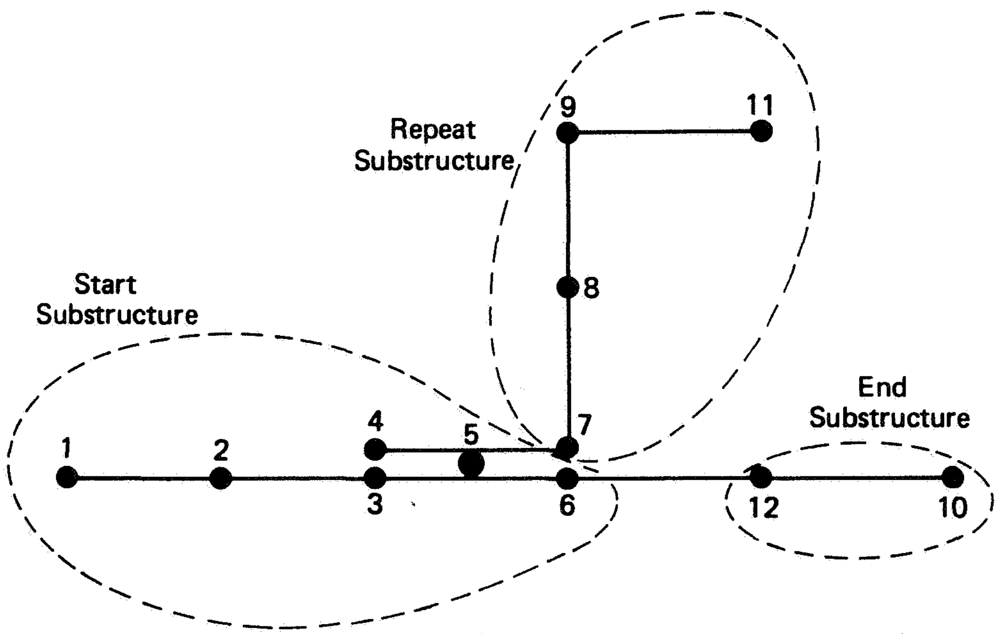
2.6.4 Some Restrictions on Substructuring Non-Repetitive Panels

Whenever a panel without repetitive structural groups is idealized with more than one substructure type, care must be exercised in the substructuring process. The panel must be divided such that any one substructure contains only one unconnected piece of structure. To illustrate this, Figure 2.10 is presented. This skin-stringer assembly is divided into three substructures. Node 3 is not attached to node 4, node 6 is not connected to node 7 and node 5 is used to attach the stringer to the skin. In Figure 2.10(a), the repeat and end substructures defy the restriction stated above, because in the repeat and end substructures, there are two discontinuous or unconnected pieces of structures. In the end substructure, the structure containing nodes 9 and 11 is not attached to the piece of structure that contains nodes 12 and 10, and in the repeat substructure, the piece of structure containing nodes 7 and 8 is not attached to node 6. Therefore, there are two unconnected structural pieces in each of the two substructures, repeat and end. Figure 2.10(b) is an example of a valid selection of nodes for this problem. Each substructure contains only one continuous piece of structure.

Another restriction is in the input order of the nodes. The nodes should be ordered such that the input list of nodes can be separated into distinct groups, each group related to a different substructure. The start substructure nodes should be input first, repeat substructure nodes, second, and the end substructure nodes last. What is important here is the input order of nodes, not the user node numbers. If the nodes of Figure 2.10(b) are input in the same order as the user node numbers, an incorrect data set will result. Nodes 9 through 11 would be out of order. Instead, the input order should be (1,2,3,4,5,6,7,8,9,11,12,10). The first group of nodes for the start substructure would be (1 to 6), second group for the repeat substructure, (7,8,9,11) and the last group for the end substructure, (12 and 10).



(a) Invalid Selection of Nodes for Substructures



(b) Valid Selection of Nodes for Substructures

Note: Numbers Shown are Users Node Numbers

Figure 2.10 Examples of Node Restrictions in Substructures

2.7 Upper and Lower Bound Loads

The panel upper bound load is required to increase the efficiency of the method used in extracting the lowest eigenvalue. This panel upper bound is defined as the least of the element upper bound loads. An element upper bound load is the buckling load of a plate element with interior sides completely restrained. For a plate element with specified boundary conditions on one side, the upper bound load is the buckling load for the plate with the interior side completely restrained and the exterior side subjected to the specified boundary conditions.

The upper and lower bound loads can be specified as input to BUCLASP2. If the bounds are not specified, an approximate upper bound load will be computed (Reference 1) and the lower bound load will be set to zero. The minimum eigenvalue for the structure should be between these bounds. For most problems the upper bound load calculated as above works very well, but in some extremely rare instances it is possible that no eigenvalues will be extracted within the bounds. For these cases, the calculated upper bound is automatically increased by 20% and a search is made between the old and new upper bound loads.

For a structure with buckling load very close to the upper bound load, it is possible that the minimum eigenvalue will not be extracted. If this occurs, the determinant values printed out for the guess loads should be inspected for any irregularities. Normally, this irregularity is evidenced by a steady decrease in determinant value followed by an increase as the load is incremented, with no indication of a root having been encountered. In such cases there is a very strong possibility for an eigenvalue to exist between the load steps where the irregularity occurred. In such cases, these loads should be used as the bounds for the problem and re-run.

2.8 Mode Shapes

The relative displacements may be computed for the buckling load corresponding to the critical wave number. The relative displacements are computed for each element with respect to its local coordinate system. They can be computed at evenly spaced prescribed points along the width of any plate element. From the output of relative displacements, the mode shape can be hand plotted.

2.9 Modelling of Riveted Connections

This section deals with the modelling of riveted connections. As an example, see Figure 2.11. If the rivet is ignored in the idealization, the stiffener would be assumed to be bonded to the skin. A suggested modelling technique is presented here to more correctly depict the behavior of riveted connections.

The rivet is idealized as a line at nodes 4 and 5. In Figure 2.11(a) the plate elements 2 and 4 are offset at node 4 as shown. Node 5 is equivalenced to node 4 to create an attachment between these nodes. The plate elements 2 , 3 , 4 , and 5 are all joined at node 4, the rivet line, but node 2 of element 2 and node 3 of element 3 are not connected and they are free to deform independently. Nodes 6 and 7 of elements 4 and 5 respectively, are also free to move independent of each other. This modelling is approximate in the sense that the connection between the stiffener and skin is reduced to a line connection.

First, make an initial run with this idealization shown in Figure 2.11(a) and investigate the mode shapes to see if they are feasible. For an example of mode shapes not being feasible, assume that the downward deflection of node 2 in the Z_G direction if greater than the downward deflection of node 3 in the same direction. Wherever this type of physical unreality occurs, join the elements together at these nodes and rerun the problem. For the example cited above, the connection of nodes 2 and 3 is accomplished by making node 2 equivalent to node 3. Offset element 3 as indicated in Figure 2.11(b).

In the original idealization shown in Figure 2.11(a), nodes 2 and 6 seem unnecessary for the first trial analysis. Plate elements 1 and 2 and similarly elements 4 and 8 could be combined into one element. The only reason for including nodes 2 and 6 in the example is to compare the displacements at these locations with nodes 3 and 7 of the stiffener, to see if any unrealistic deflections occur at these points. Actually, the displacements along the junction line between the skin and stiffener top flange should be investigated to check the feasibility of the deformed shapes.

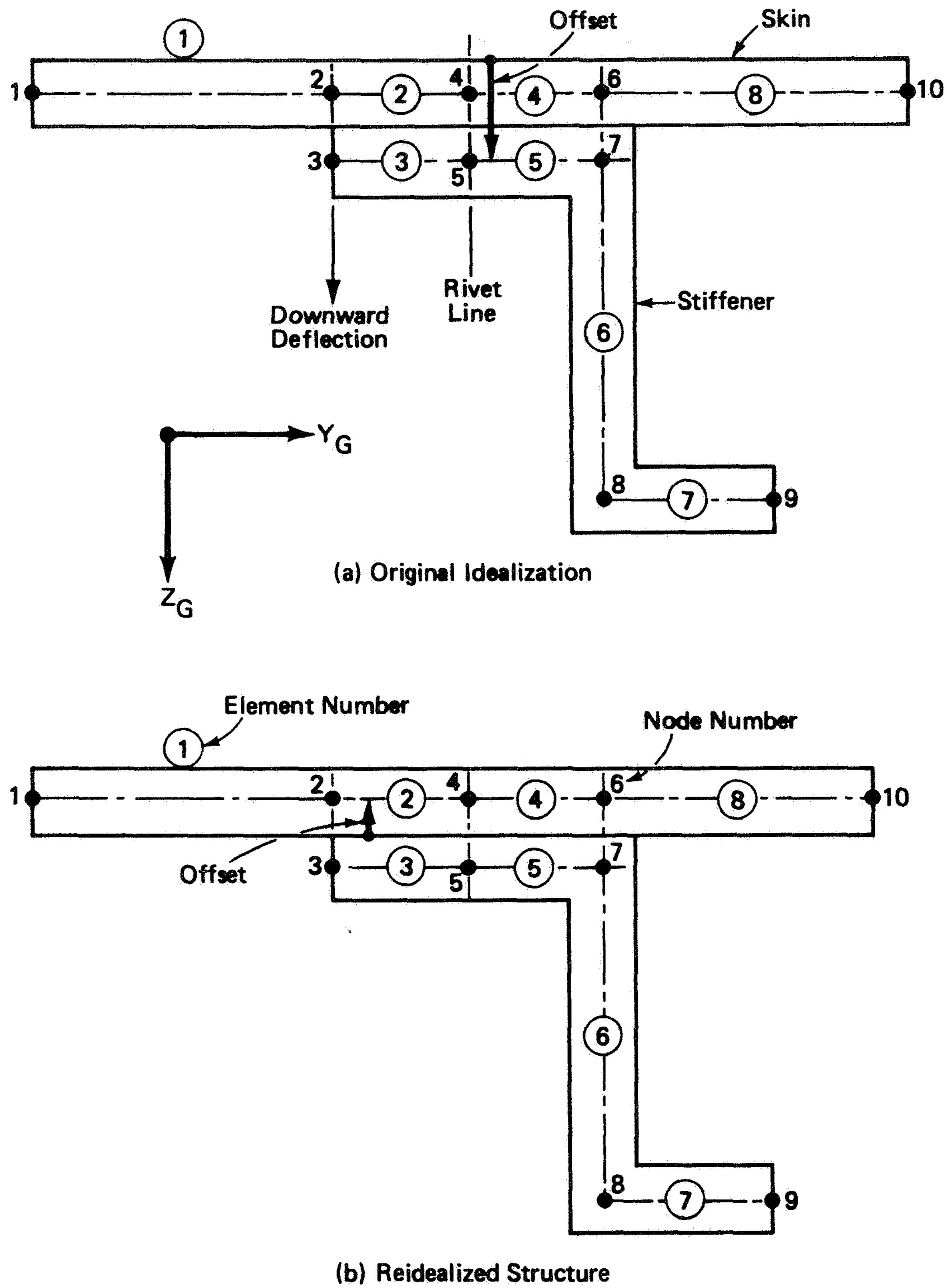


Figure 2.11 Riveted Connection Example

3.0 PROGRAM COMPUTER DETAILS

3.1 Machine Requirements

The BUCLASP2 program is written for the CDC 6600 series computers. It requires the use of a card reader, line printer, disk storage, a minimum of zero and a maximum of one tape drive.

3.2 Operating System

The program runs under the SCOPE 3.1 or KRONOS 2.0 operating systems. All system routines used are assumed to be standard CDC release. With the exception of four special purpose routine in COMPASS, all source routines are coded in CDC FORTRAN IV. The overlay loading feature is used.

Two Langley Research Center routines are used.

JPARAMS COMPUTER PROGRAMMING MANUAL
Volume I, Section K5.1 date 6-9-71

This routine makes certain job parameters available to the user.

SIMEQ COMPUTER PROGRAMMING MANUAL
Volume I, Section F4.1 date 8-1-68

This routine solves a set of linear equations.

3.3 Storage Allocation

The program will LOAD and EXECUTE with a field length of 77000_8. The field length estimate for the program is dependent upon the data set. The space for the buckling determinant is dependent upon the size of the three blocks of the determinant definition.

When the eigenvector and relative displacements are also wanted the user must take into account in field length allocation that the start substructure, each repeat substructure and the end substructure have to be stored in core.

The data processing overlay prints an estimate of field length required for the other overlays. Table 3.1 gives field lengths for some of the test cases.

3.4 Timing and Output Estimates

Time consumption for one data set depends on various factors:

a. Number of wave numbers investigated.

b. Number of nodes, plate and beam element defined for panel. The size of buckling determinant is proportional to number of unconstrained nodes.

c. Number of plate elements with stiffnesses which are the same.

The actual computer time used for some of the test cases are presented in Table 3.2.

In general, for single data set runs, and with the intermediate printout switches off, the program will generally generate from 30 to 100 pages. The number of wave numbers is a primary factor on the amount of printout. The intermediate printout should be used with care as it can be voluminous.

3.5 Disk File and Tape Utilization

BUCLASP2 uses a maximum of four files in addition to the standard input and output. The four files are scratch files used for internal information transfer.

The files referenced are:

(1)	INPUT	Standard Input (Card Reader)
(2)	OUTPUT	Standard Output (Line Printer)
(3)	TAPE1	Scratch File (Binary)
(4)	TAPE2	Scratch File (Binary)
(5)	TAPE3	Scratch File (Binary)
(6)	TAPE4	Scratch File (Binary)

3.6 Control Cards

There are basically three modes of execution, from

(a) source

(b) relocatable binary

(c) absolute binary

In the following, use of specific control cards has been avoided, rather the required sequence to operations is specified. All file names with the exception of BUCLASP are arbitrary. All overlays have the name BUCLASP, thus a file BUCLASP is generated at load time. For the cases above

(a) 1. Obtain a source file, PROG, from permanent storage (Cards, TAPE, permanent disk file, etc.).
 2. Compile source file placing relocatable binary on BPRG.
 3. Load BPRG.
 4. Execute from BUCLASP

(b) 1. Obtain a relocatable binary file, BPRG, from permanent storage.
 2. Load BPRG.
 3. Execute from BUCLASP

(c) 1. Obtain an absolute binary file, BUCLASP, from permanent storage.

2. Execute from BUCLASP.

TABLE 3.1 FIELD LENGTHS

DATA SET	NUMBER OF BLOCKS	HALF-BAND SIZE	SIZE (IN OCTAL) FOR LOADING	SIZE (IN OCTAL) FOR DISPL	MAXIMUM NUMBER OF BLOCKS IN 77 k
2A	7	13	60320	33150	68
4A	6	9	56610	30700	90
5	5	17	62040	35350	26
6A	7	11	60340	33200	50
11	6	13	61150	35010	27
18A	1	48	62620	40510	

<u>Assuming</u>

Length of (1,0) Overlay = 45100 (Octal)
(2,0) Overlay = 56240 (Octal)
(3,0) Overlay = 27350 (Octal)

TABLE 3.2 COMPUTER TIME

DATA SET	ORDER OF BUCKLING DET.	NUMBER OF WAVE NUMBERS	TOTAL CP TIME
2A	60	1	14
4A	48	1	20
5	64	1	18
6A	72	1	17
11	100	1	26
18A	48	1	50

Data Sets 2A - 11 were repeated substructure problems.
Data Set 18A was a start substructure only.

The CP time used varies nearly linearly with the number of wave numbers investigated.

DATA SET	NODES	NUMBER OF PLATES	BEAMS	SUBSTRUCTURES
2A	7	11	0	7
4A	8	4	3	6
5	8	10	0	5
6A	10	9	0	7
11	16	13	2	6
18A	12	12	0	1

4.0 PROGRAMMED DIAGNOSTIC MESSAGES

There are two types of error messages. The first kind is a message followed by routine name and number. This type is fatal to further processing, so an exit is taken. The second type is used in the input data processing routines to indicate a data error has been detected, but an attempt will be made to process the rest of the input data. This kind has a message, but no number.

Routines which print diagnostic messages.

DATAPRO	Input Data Processing Routines
FINDIN	
BLKDEF	
LCNTRL	
DM	
GAPUPP	
DB	
SBLKDT	
DBLERT	
STORE	
PRDMTX	
PROOT	
SOLVE	
DISPLAC	
FETCHD	
READTR	
FNLDIS	

DATAPRO

802 TOO MANY NODES
Card 4 Field 1

804 TOO MANY ELEMENTS
Card 4 Fields 2,3 and 4

806 TOO MANY BEAMS
Card 4 Field 2

808 TOO MANY PLATES
Card 4 Fields 3 and 4

810 BAD EQUIVALENT NODE DATA
E Card

812 BAD INTERRELATIONSHIP NODE DATA
C Card

901 NUMBER OF VALUES, III, IN M-LIST EXCEEDS 30
Cards 6 and 7

902 END OF FILE ENCOUNTERED BEFORE L
L Card was not found

903 NON ELEMENT DATA WAS ENCOUNTERED OUT OF ORDER

904 NUMBER OF NODAL SPRING STIFFNESS SETS EXCEEDED NUMBER OF NODES IN DATA SET

905 NUMBER OF PLATE ELEMENT OFFSET CARDS EXCEEDED THE NUMBER OF PLATE ELEMENTS IN DATA SET

906 NUMBER OF REPEAT SUBSTRUCTURE INTERRELATIONSHIP NODE PAIRS INPUT EXCEEDED MAXIMUM OF IIIII

907 NUMBER OF EQUIVALENT NODE DEFINITION PAIRS INPUT EXCEEDED MAXIMUM OF IIIII

908 INPUT MATERIAL PROPERTY TABLE FAILED

909 INPUT OF THICKNESS TABLE FAILED

910 NUMBER OF NODE DEFINITIONS INPUT, XXXXX, DID NOT AGREE WITH NUMBER SPECIFIED IIIII

911 NUMBER OF ERRORS DETECTED IN PANEL SUBSTRUCTURE DEFINITION = IIIII

912 NUMBER OF PLATE ELEMENTS INPUT EXCEEDED NUMBER SPECIFIED

914 INVALID LOAD OPTION, IIIII, SPECIFIED
Card 5 Field 1

915 INVALID WAVE NUMBER SEARCH OPTION, IIIII, SPECIFIED
Card 5 Field 2

916 IIII ERROR(S) DETECTED IN DATA

917 CURVED PANEL REPEAT SUBSTRUCTURE INTERIOR ANGLE EXCEEDS 180 DEGREES
Card 4 Field 6

918 CURVED PANEL REPEAT SUBSTRUCTURE INTERIOR ANGLE MULTIPLIED BY NUMBER OF REPEAT SUBSTRUCTURES EXCEEDS 360 DEGREES
Card 4 Field 6

919 CURVED PANEL REPEAT SUBSTRUCTURE INTERIOR ANGLE EQUALS ZERO

Card 5 Field 6

MATERIAL TABLE INPUT, BUT NO THICKNESS TABLE PRESENT

THICKNESS TABLE INPUT, BUT NO MATERIAL TABLES PRESENT

NUMBER OF MATERIAL TABLES INPUT EXCEEDS MAXIMUM OF III

INVALID PLATE TYPE

Card P Field 5

NUMBER OF LAMINAS EXCEEDS MAXIMUM OF 25

Number of Plates Laminas $\leq$ 25.

Card P Field 7

INVALID PLATE OFFSET SWITCH, III

Card P Field 6

INVALID MATERIAL PROPERTIES INPUT FORMAT OPTION, III

Card P Field 8, or

Card B Field 6

INVALID N_{22} LOAD SELECTION SWITCH, III

Card P Field 9

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS WAS NEGATIVE

Card P Field 10

INVALID MATERIAL TABLE INPUT OPTION, III

Card P Field 11

INVALID BEAM TYPE
Card B   Field 4

NUMBER OF LAYERS EXCEEDED MAXIMUM OF 35
Number of Beam Layers $\leq$ 35

NUMBER OF NODAL CARDS READ EXCEEDS NUMBER DECLARED

ILLEGAL BOUNDARY CONDITION, IIIII ON NODE III

NUMBER OF S CARDS, IIIII, DOES NOT AGREE WITH NUMBERS
OF SPRUNG NODES IIIII

USER ID, IIIII, ON S CARD, IIIII, INVALID

USER ID, IIIII, IN REPEAT SUBSTRUCTURE INTERRELATIONSHIP
PAIR, IIIII, IS INVALID

USER ID, IIIII, IN EQUIVALENT NODE PAIR, IIIII, IS INVALID
Card E

USER ID, IIIII, IN, AAAAA, SUBSTRUCTURE DEFINITION IS INVALID
Card D

NODE1(IIII) DOES NOT PRECEDE NODE2(IIII) OF, AAAAA,
SUBSTRUCTURE DEFINITION
Card D

END NODE(IIII) OF, AAAAA, SUBSTRUCTURE IS NOT CORRECTLY
RELATED TO START NODE(IIII) OF, AAAAA, SUBSTRUCTURE
Card D

NODE(IIII) FOR PLATE(IIII) IS INVALID
Card P   Fields 3 or 4

NODE(IIII) FOR BEAM (IIII) IS INVALID
Card B   Field 3

USER ID, IIIII, FOR PLATE ELEMENT OFFSET SET, IIIII,
IS INVALID
Card F   Field 2

NUMBER OF PLATE ELEMENTS INPUT (IIIII) DOES NOT AGREE
WITH NUMBER SPECIFIED

NUMBER OF BEAM ELEMENTS INPUT (IIIII) DOES NOT AGREE
WITH NUMBER SPECIFIED

IIIIIIIII, IS INVALID NODE NUMBER

NODE I, IIIIIIIII, IS NOT IN START SUBSTRUCTURE

NODE J, IIIIIIIII, IS NOT IN REPEAT SUBSTRUCTURE

NODE, IIIII, IN START SUBSTRUCTURE SHOULD BE PART
OF A REPEAT SUBSTRUCTURE INTERRELATIONSHIP PAIR

FINDIN

FIRST NODE XXX GREATER THAN LAST NODE

NO INTERIOR NODES BETWEEN FIRST NODE XXX AND LAST NODE XXX

BEAMDF

INVALID TABLE POINTER DATA

See discussion on Table Input.

PLTDEF

INVALID TABLE POINTER DATA

See Section 6.4.

BLKDEF

708 IIIII, ERRORS DETECTED IN SUBSTRUCTURE DEFINITION NODE PAIRS

710 PANEL WITH REPEAT SUBSTRUCTURE BUT NO END SUBSTRUCTURE DEFINED

711 SUBSTRUCTURE DEFINITION PAIR IS OUT OF ORDER

713 NO SUBSTRUCTURE DEFINITION NODE INPUT

714 PANEL MATRIX DEFINED IS NOT SQUARE

715 START COLUMN DEFINITION OF SUBSTRUCTURE AAAAAA AND AAAAAA SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

716 END COLUMN DEFINITION OF SUBSTRUCTURE, AAAAAA, AND AAAAAA SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

717 ROW DEFINITION OF SUBSTRUCTURE, AAAAAA AND AAAAAA, SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

718 SUBSTRUCTURE AAAAAA AND SUBSTRUCTURE AAAAAA ARE NOT INTERRELATED PROPERLY
Examine Substructure Defintion and Element Connectivity. See Section 2.6.4.

719 THE SUBSTRUCTURE DEFINITION OF START SUBSTRUCTURE AND ELEMENT CONNECTIVITY OF START SUBSTRUCTURE IS NOT CORRECT Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

720 NO EQUIVALENT NODES SPECIFIED FOR A PROBLEM WITH BEAM ELEMENTS

721 IIIII, ERRORS FOUND IN PROCESSING EQUIVALENT NODES

724 ELEMENT UNASSIGNABLE TO A SUBSTRUCTURE

BOUNDARY CONDITION, II, NOT ALLOWED ON BEAM DEFINITION NODE, IIIII

BEAM ELEMENT, IIIII WITH NODE, IIIII HAS NO EOUIVALENT NODE DEFINED

EQUIVALENT NODES, IIIII, AND IIIII, HAVE CONFLICTING BOUNDARY CONDITIONS, IIIII, AND IIIII

LCNTRL

901 DOUBLE ROOT COULD NOT BE SUCCESSFULLY BYPASSED

902 ZERO DETERMINANT COULD NOT BE SUCCESSFULLY BYPASSED

903 SEARCH FOR BUCKLING CONDITION DID NOT STABILIZE IN SPECIFIED NUMBER OF INTERATIONS
Check for Panel Being in Buckled Condition for Zero Load

DM

30 DOUBLE ROOT ENCOUNTERED IN UPPER BOUND CALCULATION

GAPUPP

MATRIX REDUCTION FAILED

DB

906 MATRIX BLOCK DEFINITION FAULTY

SBLKDT

THE MATRIX HAS A ZERO ROW

MATRIX SIZES OR RELATIVE POSITIONS ARE INCOMPATIBLE
Zero Determinant at Block XXX

DBLERT

DOUBLE ROOT DETECTED

STORE

22 NODE NUMBER NOT FOUND IN SUBSTRUCTURE ROW DEFINITIONS

24 NODE NUMBER NOT FOUND IN SUBSTRUCTURE COLUMN DEFINITIONS

PRDMTX

5 ELEMENT NODAL INTERCONNECTIVE MATRIX SINGULAR

PROOT

ZARK FAILED TO CONVERGE IN THE MAXIMUM NUMBER OF ITERATIONS SPECIFIED

ZARK FAILED - A ZERO IN THE PATH OF A SUBSEQUENT ONE
Complex Root Found That is Not One of a Conjugate Pair

SOLVE

8 SINGULARITY ENCOUNTERED IN ATTEMPT TO PRODUCE STIFFNESS MATRIX

DISPLAC

INSUFFICIENT CORE IS AVAILABLE TO CONSTRUCT THE STIFFNESS MATRIX FOR THE EIGENVECTOR SOLUTION INCREASE FIELD LENGTH BY ___________

THE STIFFNESS MATRIX CANNOT BE DECOMPOSED

FETCHD

14 ATTEMPT FETCH A NON-EXISTENT NODAL DISPLACEMENT COMPONENT

READTR

10 ID ON NODAL TRANFORMATION INVALID

12 ID ON ELEMENTAL TRANSFORMATION INVALID

FNLDIS

20 ATTEMPT TO INVERT ELEMENTAL TRANSFORMATION MATRIX FAILED

5.0 Restrictions

The following restrictions apply to this version of the program.

5.1 Analysis Oriental Restrictions

a. The special loading cases are described in Section 2.5.

b. Each layer is orthotropic with respect to plate axes.

c. Prebuckling deformations are ignored and linear theory (small deformations and linear elastic materials) is used.

d. The cross-section is uniform in the axial direction

e. Loaded edges of each element forming the cross-section are simply supported.

f. The arc of a curved plate element has to be less than or equal to 180 degrees.

g. Buckling load will not be computed for a structure already buckled by the input loads.

h. When the buckling load is nearly equal to the upper bound load, it is possible that the buckling load will not be found. See Section 2.7 for a possible remedy for this problem.

i. The curved panel repeat substructure interior angle ($\Delta\Theta$) must be less than or equal to 180 degrees.

j. The total interior angle of a curved panel with repeated substructures must be less than or equal to 360 degrees.

5.2 Programming Oriented Restrictions

a. Maximum number of elements definable in the three substructures is 35, and the maximum number of nodes is 35.

b. Maximum number of types of plate elements is 10. These are of the same type in the sense that their lamina stiffness matrices, loadings and radii are of the same content.

c. The maximum number of layers is 25 for plate elements.

d. Maximum number of beam elements is 10.

e. The maximum number of layers is 35 for beam elements.

f. Two real roots of the determinant expression det (DT) = 0 are considered double if they differ by less than 0.00003%.

g. The imaginary part of the complex roots of the determinant expression det (DT) = 0 is exactly set to zero if its numerical value is less than 10^{-6}, or when it is less than 10^{-5} times the real part of the number. A similar test applies to the real part of the number.

h. It is assumed that no coupling exists between bending and stretching when all of the elements of the B_{ij} matrix are less than 1.0.

i. Maximum number of wave numbers that can be investigated in one data set is 30.

j. The minimum number of elements is either 2 plates or 1 plate and 1 beam.

k. There must be at least 1 interior node in each block type.

l. Node restrictions in blocks; see Section 2.10.

m. An element cannot have nodes both in the start and end substructures, which means closed cylinder problems must be done with a single substructure.

5.3 Mathematical Oriented Restrictions

In the buckling calculation the process is done strictly incore where the number of repeat blocks is arbitrary, but will be limited in practice by the accumulation of rounding errors.

The eigenvector computation requires that the buckling load be well isolated. Problems which buckle without a determinant change of sign will have multiple eigenvectors for the buckling load.

6.0 PROGRAM INPUT

The data input to this program consists only of cards, and no data tapes are required.

6.1 Input Data Format

Fields of 5 or less are right adjusted integers. Fields of 10 are floating point numbers with format F10.0.

CARD 1 (8A10)

Columns	Column 1 must be blank.
2-80	Title of run. Any characters anywhere in columns. This title is printed out in several strategic places in the output for the purpose of identification.

CARD 2 (16I5) Intermediate Print Control (IPC) Array

The intent of the options on this card is for diagnostic checking.

Columns		
1-5	IPC(1) = 1	Print intermediate results (1)
	= Blank	Suppress print
	This option prints out control lists obtained from input data.	
6-10	IPC(2) = 1	Print intermediate results (2)
	= Blank	Suppress print
	This option prints out the p roots of the determinant expression det (DT) = 0 (equilibrium equations) during the upper bound calculation.	
11-15	IPC(3) = 1	Print intermediate results (3)
	= Blank	Suppress print
	This option prints out the elemental and merged stiffness matrices along with the determinant calculation information during the upper bound calculation.	

Columns

16-20	IPC(4) = 1	Print intermediate results (4)
	= Blank	Suppress print

This option prints out information about the element upper bound initial estimates and the actual upper bound.

21-25	IPC(5) = 1	Print intermediate results (5)
	= Blank	Suppress print

This option prints out the p roots of the determinant expression det (DT) = 0 (equilibrium equations) during the panel buckling calculation.

26-30	IPC(6) = 1	Print intermediate results (6)
	= Blank	Suppress print

This option prints out the elemental matrices during the panel buckling calculation.

31-35	IPC(7) = 1	Print intermediate results (7)
	= Blank	Suppress print

This option prints out the merged stiffness matrices and determinant calculation information during the panel buckling calculation.

36-40	IPC(8) = 1	Print intermediate results (8)
	= Blank	Suppress print

This option prints out the compacted stiffness matrix, the element p roots and the element ω_i.

CARD 3 (16I5) Program Control Array

Columns

1-5	JPC(1)	= 1	Calculate panel upper bound only
		= 0 (Blank)	Proceed as normal
6-10	JPC(2)	= 0 (Blank)	No relative displacements
		= 1	Compute relative displacements
11-15	JPC(3)	= 1	Data check only is performed
		= 0 (Blank)	Non data check only mode
16-20	JPC(4)		Number of iterations allowed in buckling calculation
		= Blank	Number will be defaulted to 100
		= η	where $1 \leq \eta \leq 100$
21-25	JPC(5)		Number of iterations used in eigenvector calculation
		= Blank	Number will be defaulted to 4
		= η	where $4 \leq \eta \leq 10$

Option should be used with care. Can be used to find multiple eigenvectors for problems with coincident roots by running problem with η iterations and then with $\eta + 1$ iterations.

CARD 4 Problem Characteristics

Columns

1-5	Number of Nodes in the section (i.e. in start substructure, one repetitive substructure and the end substructure)
6-10	Number of Beam elements in the section
11-15	Number of Flat Plate elements in the section
16-20	Number of Curved Plate elements in the section
21-25	Curved Panel Repeat Option = 0 (Blank) Non Curved Panel Option = 1 Curved Panel with multiple repeat blocks
31-40	Curved Panel Repeat Block Included angle ($\Delta\Theta$) See Section 2.6.2 for discussion.
41-50	Length of the section
51-60	Transverse Load or Strain value
61-70	Biaxial Load Ratio for first plate element Input only when this option is selected.

For the transverse load or strain value, input a negative value for tension and a positive value for compression. Biaxial load ratios are computed with the same sign convention as above.

CARD 5 Analysis Options

Columns

1-5 Load Options

= 1 N_{11} (force/length) applied to first plate is varied with a N_{22} transverse load of constant value applied to "affected" plates. The N_{22} load can have an initial value plus be a linear function of N_{11} as specified by biaxial ratio. (Generally, set $N_{22} = 0$ for a biaxial ratio problem)

= 2 N_{22}, transverse load is varied at the same value on all affected plates with an initial constant N_{11} being applied to all plates.

= 3 N_{22} (force/length), transverse load is varied at the same value on all "affected" plates with an initial constant strain ε_{11} being applied to the first plate element.

6-10 MOPT Option control for the loop on the longitudinal wave number M.

= 1 Start the loop at wave number MMI and loop until a minimum load is found, then interrupt (Max. 30 loops)

=2 Start the loop at wave number MMI and loop to wave number MMA (Max. 30 loops)

=3 Start the loop at first value of M-list and loop through M-list until a minimum load is found, then interrupt (M-list must be input on cards 6,7) (Max. 30 loops)

=4 Start the loop at first value of M-list and loop through M-list. (M-list must be input on cards 6,7) (Max. 30 loops)

11-15 MMI Starting value for the loop on the longitudinal wave number M

Set = 1 for options 3 and 4

16-20 MMA End value for the loop on the longitudinal wave number M

Set = number of values in M-list for options 3 and 4

Columns

21-25	NLW	Lower Limit for root searching criteria (If left blank, NLW is defaulted to 0)
26-30	NUP	Upper Limit for root searching criteria. If left blank, NUP is defaulted to 1 NLW $\geq$ 0, NLW $<$ NUP. The program does a complete solution of the data for each root searching criteria $\eta/\eta+1$ where NLW $\leq$ η $<$ NUP. (η is the number of roots below the trial load.)
31-35		Default number of element subdivisions for relative displacement calculation (defaulted to 5, if left blank)
41-50	SLW	Lower bound load (first plate element) for search interval (defaulted to 0.0, if left blank)
51-60	SUP	Upper bound (first plate element) load for search interval. If left blank an upper bound is calculated for the structure for each M value. If specified SLW $<$ SUP. Note that the same SLW, SUP pair is used for every M value to be searched.

See Section 2.5 for discussion of load options and Section 2.7 for discussion of upper bounds. For a discussion of the root searching criteria, see Section 6.1 of Reference 1.

CARD 6	M-list (limited to 30 values) (List of wave numbers)
Columns	
1-5	First value of M-list
6-10	Second value of M-list
.	
.	
.	
75-80	Sixteenth value of M-list
CARD 7	M-list (continued)
	(Use this card if necessary; if not omit)
1-5	Seventeenth value of M-list
.	
.	
.	
65-70	Thirtieth value of M-list

CARD T-1 Lamina Thickness Table

<u>Columns</u>

1-5 Letters "THICK"

11-80 ..., ..., value, .../

where value may be $\pm$ nnn.nnn

or $\pm$ n.nnnn E $\pm$ nn

Number of significant digits is limited to 14

The table is terminated by the character slash (/). If the entries of a table exceed one card, the table may be put on more cards using columns 11-80 (columns 1-10 blank) with the last table value followed by a slash. The values in the table are delimited by commas and physical end of card.

Omit card if Table option not used for element property input. See Section 6.4 for discussion of table use.

Note: Only one thickness table is allowed per data set.

CARD T-2 Lamina Material Properties Table

Columns

1-5	Letters "TABLE"
9-10	Table Number
11-80	..., ..., value, .../

Same rules for this table as the one on CARD T-1

Omit card if Table option is not used for element property input.
See Section 6.4 for discussion of table use.

Table Lengths

Element	Length
Plate	4
Rectangular Beam	3
Circular Beam	2

CARD C Repeat Substructure Interrelationship Nodes

Columns

1-1	Letter "C"	
3-5	Node i	Pair 1 (this card)
8-10	Node j	
.	Node i of start substructure is interrelated to Node j of repeat substructure	
.		
.		
73-75	Node i	Pair 8 (this card)
78-80	Node j	

Repeat this card for each set of 8 interrelationship node pairs until all interrelationship node pairs have been input.

Note: Interrelationship nodes must be interior nodes, and must be included if the number of repeat blocks $\geq$ 2.

See Section 2.6.3 for discussion. Omit this card when the number of repeat substructures is less than 2.

CARD E Equivalent Nodes

Columns

1-1	Letter "E"	
3-5	Node i	Pair 1 (this card)
8-10	Node j	
.		
.		
.		
73-75	Node i	Pair 8 (this card)
79-80	Node j	

Repeat this card for each set of 8 equivalent node pairs until all equivalent node pairs have been input. See section 6.2 for discussion of equivalent nodes.

Note: Equivalent nodes must be interior nodes. This card is used to specify those nodes which move together structurally. Omit this card if no equivalent nodes exist.

CARD N Nodal Definition

Columns

Columns	
1-1	Letter "N"
3-5	User Node Number
10-10	Nodal Boundary Condition

= blank	Interior
1	Simple Support
2	Clamped
3	Free
4	Sprung (Card S must follow)

21-30	Y - coordinate of node in right-handed global coordinate system
31-40	Z - coordinate of node in right-handed global coordinate system

Internal node number is determined by input position, i.e. first node input is internal node one, etc.

CARD D Panel Substructure Definition

Columns

1-1	Letter "D"
3-5	The number of substructures that the buckling determinant is divided into. This includes the start and end substructures plus the repeat substructures.
8-10	User node number which the Lowest Internal Node Number in Start Substructure
13-15	User node number which is the Highest Internal Node Number in Start Substructure
18-20	User node number which is the Lowest Internal Node Number in Repeat Substructure
23-25	User node number which is the Highest Internal Node Number in Repeat Substructure
28-30	User node number which is the Lowest Internal Node Number in End Substructure
33-35	User node number which is the Highest Internal Node Number in End Substructure

A substructure is left undefined by not specifying substructure definition node pair.

Permissible Combinations

Start Substructure Only
Start and End Substructures Only
Start, Repeat (one or more) and End Substructures

It is recommended that the start substructure be larger of the three substructures for efficiency reasons in the determinant calculations. Note: See card N for definition of Internal Node Number.

CARD S Nodal Spring Stiffness

<u>Columns</u>

1-1	Letter "S"
3-5	User Node Number
11-20	Local w component for node
21-30	Local θ component for node
31-40	Local v component for node
41-50	Local u component for node

See Section 2.4 for discussion of sprung nodes.

Omit this card if there are no sprung nodes.

CARD F   Plate Element Offset

Columns

1-1		Letter "F"
3-5		User Plate Number
11-20	OFF1	Offset z_0 in the local z direction at the starting end ($y = -b/2$) of the plate element, measured positive in the positive z direction, from the negative surface of the element to the grid.
21-30	OFF2	Offset y_0 in the local y direction at the starting end ($y = -b/2$) of the element, measured positive in the positive y direction, from the end of the element to the grid.
31-40	OFF3	Offset z_0 at the end $y = +b/2$ of the plate element. Measured similarly to OFF1.
41-50	OFF4	Offset y_0 at the end $y = +b/2$ of the plate element. Measured similarly to OFF2.

Omit this if no plate offsets exist.
See Section 2.3 for discussion of offsets.

CARD P Plate Definition

Columns	
1-1	Letter "P"
3-5	User Plate Number
8-10	Plate definition node I (user numbers)
13-15	Plate definition node J (user numbers)
20-20	Plate element type = 1 Flat Plate 2 Curved Plate
25-25	Element Offset Switch = 0 (blank) No offsets for this plate 1 Element has offsets
29-30	Number of laminas in element
35-35	Input format for element material properties = 0 (blank) P-1 or P-2 cards are used for materials property input 1 Material properties are input through tables.
40-40	N_{22} load selection switch = 0 (blank) The N_{22} load is applied this plate ("affected") 1 This plate will have an effective N_{22} load of ZERO
43-45	Number of subdivisions used in relative displacement calculation. If left blank, the default number specified on Card 5 is used.
50-50	Input option for material properties = 0 (blank) Engineering constants E_{11}, E_{22}, ν_{12}, G_{12} are specified 1 Lamina stress-strain Matrix Q is specified
71-80	Curved Plate Element Radius (see Section 2.2.1)

CARD P-1 Plate Thickness and Material Properties

<u>Columns</u>

1-10	T	Thickness of lamina
11-20	E_{11}	E- modulus for direction 1
21-30	E_{22}	E- modulus for direction 2. E_{22} need not be entered for isotropic laminas.
31-40	RNUA	Poisson's ratio, ν_{12}
41-50	G_{12}	G- modulus

The subscript 1 denotes the longitudinal axis and the subscript 2 the transverse axis of the plate local coordinate system.

CARD P-2 Plate Lamina Thickness and Q_{ij} Matrix

Columns

1-10 Thickness of lamina

11-20 Q_{11} element of lamina Q_{ij} matrix

21-30 Q_{12} element of lamina Q_{ij} matrix

31-40 Q_{22} element of lamina Q_{ij} matrix

41-50 Q_{66} element of lamina Q_{ij} matrix

Q_{ij} are the elements of the stress-strain matrix. See equation (4.3) of Reference 1.

CARD B Beam Definition

Columns

1-1 Letter "B"

3-5 User Beam Number

8-10 Beam Definition Node (user)

13-15 Type of Beam
= 1 General
2 Rectangular (may be laminated)
3 Circular (may be laminated)

18-20 Number of layers if laminated

25-25 Input format for element material properties
= 0 (blank) B-1, B-2 or B-3 cards are used for material property input
1 Material properties are input through tables

41-50 Angle between the local v-axis of beam element and the global Y-axis (measured clockwise, from the global Y-axis)

51-60 Area of beam (Option 1)

Beam element definition node must be equivalenced to a node of plate element.

CARD B-1 General Beam Properties

Columns	
1-10	E-modulus of beam element in longitudinal direction
11-20	G-modulus of beam element material
21-30	Moment of inertia about local y-axis
31-40	Moment of inertia about local z-axis
41-50	Warping constant for beam element about shear center
51-60	Torsion constant of bead or lip about shear center
61-70	y distance measured from the shear center to the centroid of the beam (measured parallel to local y axis)
71-80	z distance measured from the shear center to the centroid of the beam (measured parallel to local z axis)

See Section 2.2.2 for description of local coordinate system.

CARD B-2 Rectangular Beam Lamina Thickness and Material Properties

Columns

1-10 Lamina Thickness

11-20 E-modulus of lamina in longitudinal direction

21-30 G-modulus of lamina material

31-40 Width of beam element
If the width of all lamina is the same, then only the width for the first lamina need be specified.

6.21

CARD B-3 Circular Beam Lamina Radius and Material Properties

Columns

1-10 Lamina Outer Radius

11-20 E-modulus of lamina in longitudinal direction

21-30 G-modulus of lamina material

For a tube element, input the hole as the first lamina with zero E and G.

CARD L Last Card of Data Set

<u>Columns</u>

1-1 Letter "L"

This card must terminate each data set.

6.2 Use of Equivalent Nodes

Equivalent nodes are used to cause two nodes to move together structurally. Beam are attached to plate elements so beam definition nodes must always be made equivalent to plate nodes. Care must be exercised so that (1) the use of equivalent nodes does not alter a substructure definition, and (2) a node that is a left (right) node of an equivalent pair does not appear as a right (left) node of a subsequent equivalent pair. See examples below:

	not permissable	permissable
(a)	$n_1 \rightarrow n_2$	$n_1 \rightarrow n_2$
	$n_2 \rightarrow n_3$	$n_3 \rightarrow n_2$
(b)	$n_1 \rightarrow n_2$	
	$n_3 \rightarrow n_1$	

6.24

6.3 Data Stacking

CARD	ORDER		
1	1		
2	2		
3	3		
4	4		
5	5		
6 7	Next if required		
N			
D			
T-1 T-2 C E S F	Omit any cards that are inapplicable		
P			
P-1 (or equivalent) or (not both) P-2 (or equivalent)		Repeat for each lamina	All plate definition cards
B			
B-1 B-2 (or equivalent) B-3 (or equivalent)		Repeat for each lamina	All beam definition cards (Omit if no beams)
L			Last card in data set

Repeat this order of card stacking for multiple data sets.

6.4 Use of Tables

The program has a table input option to facilitate the repetitive nature of the input for the thicknesses, radii and material properties of the plate and beam elements. This option replaces the P-1, P-2, B-2 or B-3 cards. The first item of the P-1, P-2, B-2 and B-3 cards (lamina thickness or lamina radius) is specified on the T-1 card. All other items of the P-1, P-2, B-2 and B-3 cards are input on the T-2 card. These items are the material properties, E, ν, G or Q, for each layer. Each set of values on the T-2 card will be identified by a user table number. In a data set, it is permissible to use both input options for different elements, but the same input option must be used for all layers of any one element.

To use this table input, first input the proper parameter on columns 35 and 25 of the P and B cards, respectively. Then, on subsequent cards, one or more for each element, specify the table numbers for element material properties and the locations of the thicknesses or radii on the T-1 card. An example of the card is shown below.

```
(1,2,3,,,,1/  3,2,,5,6,7,6)

 thickness     material
 or radii      properties
```

The left and right parentheses are used to initiate and terminate the data for one element. The / is used to separate the T-1 and T-2 entries. The numbers to the left of / corresponds to the n^{th} entries of the T-1 card. The numbers are input in the order of the layers and separated with commas. If a number is omitted between commas, the previous integer is used for that layer. The numbers of commas to the left and right of / must always be equal.

The data for the example above will be interpreted in the following manner.

Layer No.	n^{th} Item of T-1 Card	Table No. of T-2
1	1	3
2	2	2
3	3	2
4	3	5
5	3	6
6	3	7
7	1	6

7.0 OUTPUT

The printing of the input data is coordinated with the description of the input in Section 6.1. The items of output that are produced are as follows:

1. Header Page
2. Program Control Options
   Card 3
3. Problem Characteristics
   Card 4
4. Analysis Options
   Cards 5, 6 and 7
5. Nodal Data
   Card N
6. Substructure Definition Data
   Card D
7. Repeat Substructure Interrelationship Data
   Card C. Node I is in the start substructure and Node J is in the repeat substructure.
8. Equivalent Node Data
   Card E. Node I is equivalent to Node J.
9. Table Data
   Cards T1 and T2
10. Element Data
    Cards P, P-1 (or equivalent) or P-2 (or equivalent). Each plate is accompanied by its A-, B- and D-matrices. The A-matrix represents the extensional stiffness of the plate element, while the B- and D-matrices are the coupling stiffness and bending stiffness, respectively. These matrices are computed with respect to the plate midplane.

    Cards B, B-1, B-2 (or equivalent) or B-3 (or equivalent)
11. Plate Element Input Offsets
    Card F
12. Plate Element Net Offsets
    The net ZO offsets are measured from the midplane of the element to the point that is offset to.

13. Element Transformation Data

The plate element widths, the sines and cosines of the transformation angles (local to global) at the definition nodes and the element types are printed. The sign convention for the angles are shown in Figure 5.2 of Reference 1. The plate width for curved elements is the arc length between nodes.

14. Element Substructure Assignment Data

Each element is assigned to a substructure by the following rules:

a. If all nodes are in one substructure, then element is in the substructure.
b. If one node is in the start substructure and one node is in the repeat substructure, then the element is in the repeat substructure.
c. If one node is in the repeat substructure and one node is in the end substructure, then the element is in the end substructure.
d. If one node is in the start substructure and one node is in the end substructure, then the element is in the end substructure.

This assignment information is used in the total load calculation and the relative displacement calculation.

15. Curved Panel Transformation Check

The last node of the panel is transformed from its initial position to its final position using the number of repeat substructures and panel included angle. This is supplied for user visibility of the problem.

16. Field Length Data

The field length for the buckling calculation is exact, whereas the one for the eigenvector calculation is an upper bound to the one needed.

17. Panel Upper Bound

18. Buckling Load Search History

The number of negative elements found on the diagonal of the panel matrix during the determinant calculation. The buckling determinant $= A \cdot (2^B)$. There is a history printed for each wave number. The number of negative elements indicates the number of eigenvalues that are below the trial load.

19. Element Loads

The inplane biaxial loads, N_{11} and N_{22}, and the biaxial strains, E_{11} and E_{22} for plate elements are printed here. For beam elements, the axial loads and strains are printed. The total loads, axial and transverse are also included. Sign convention used here is such that tension is (-) and compression is (+).

20. Buckling Load Computation Summary

The critical wave number among those searched is identified. The buckling load for the first element of the panel is printed for each wave number.

21. Eigenvector

For each iteration, the eigenvectors for every freedom of all nodes, with the exception of constrained or sprung nodes, are printed along with the normalizing factors. User should inspect these eigenvectors to check on convergence. These values are printed with respect to the global coordinates.

22. Relative Displacements

The element displacements are relative to the element local coordinate system.

8.0 SAMPLE PROBLEMS

The input, output and accompanying sketches of four (4) sample problems are included in this section. The circled items on the figures and discussions are user element numbers and the uncircled integers are user node numbers.

8.1 Example 1: Potpourri Input Problem

The sample input for this problem is presented for this rather arbitrary structure, shown in Figure 8.1. This example is included here to illustrate many input features of BUCLASP2.

The total structure is assumed to comprise of two more repeat substructures than is shown in Figure 8.1. Node 101 is simply supported, node 117 clamped, node 107 sprung, and nodes 104 and 113 are free to deform. Plates 17 and 18 are separated by an offset of 1 inch. 16 is a three layered circular beam and 8 is a general beam element that is offset 2 inches from the midplanes of plate elements 6 and 9 .

8.1

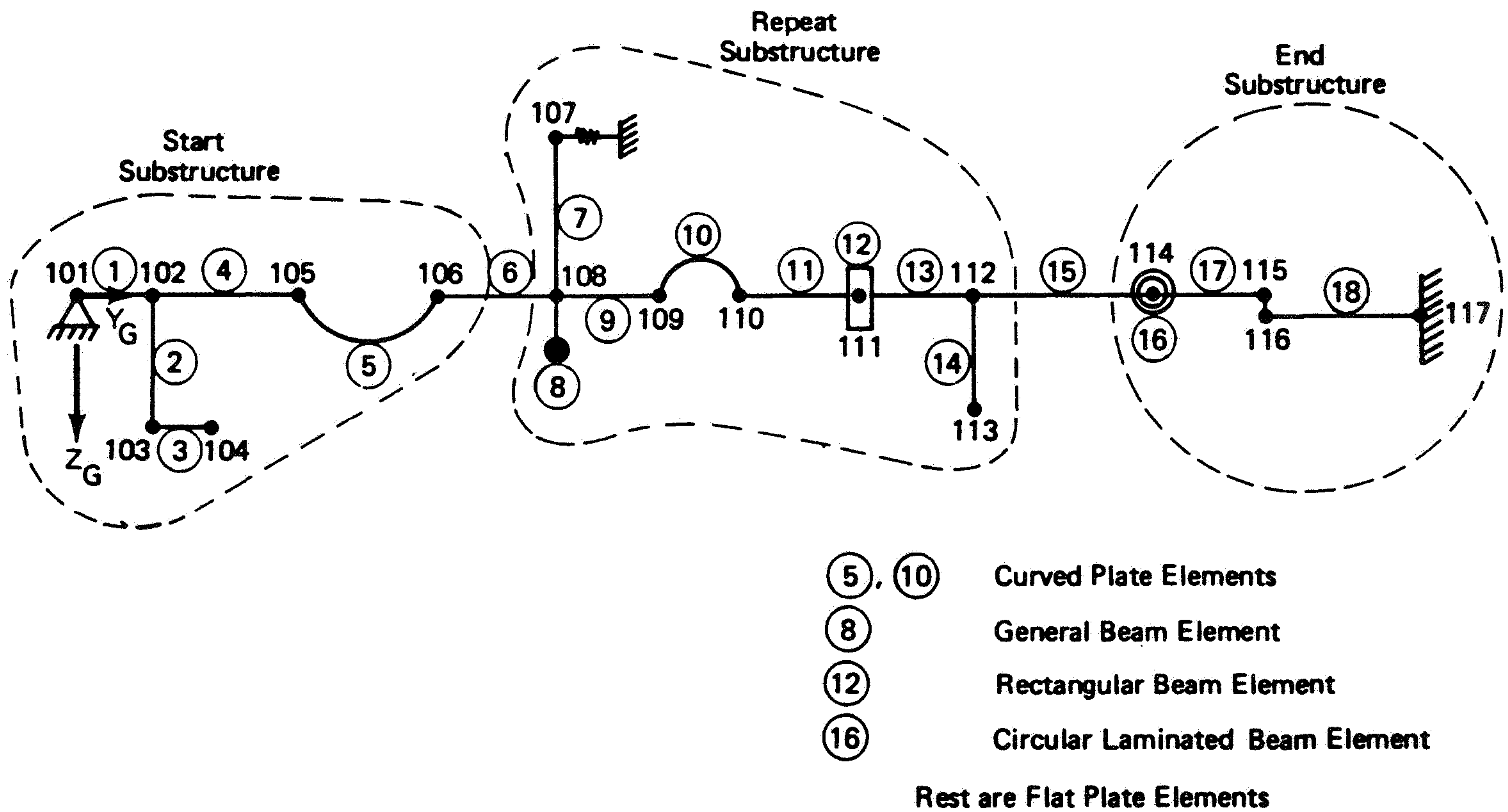


Figure 8.1 Example No. 1 - Potpourri Input Problem

POTPOURRI INPUT PROBLEM

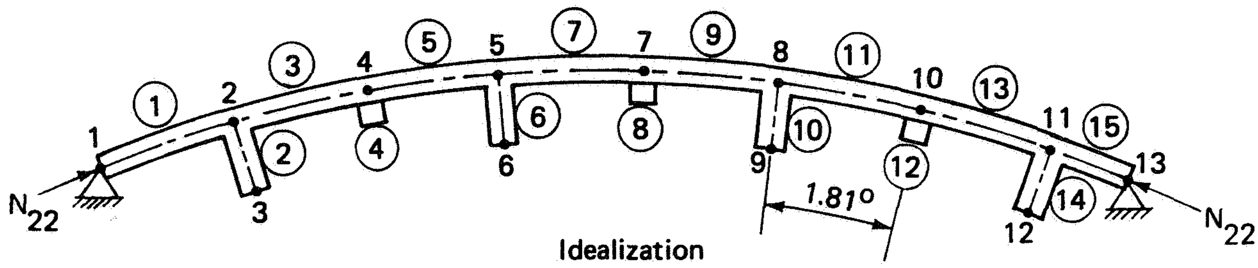
```
                1
  17     3     13     2     0                        500.      0.0      0.0
   1     2      1     1     0     1
N 101    1                 0.0        0.0
N 102                      1.0        0.0
N 103                      1.0        2.0
N 104                      2.0        2.0
N 105                      5.0        0.0
N 106                     15.0        0.0
N 107    4                21.0       -0.7
N 108                     21.0        0.0
N 109                     30.0        0.0
N 110                     36.0        0.0
N 111                     47.0        0.0
N 112                     60.0        0.0
N 113    3                60.0       14.0
N 114                     66.0        0.0
N 115                     92.0        0.0
N 116                     92.0        1.0
N 117    2               110.0        1.0
D   5  101   106   107   113   114   117
S 107          1. E05
E 115  116   108   108   111   111   114   114
C 106  112
F   6        0.0       0.0       2.0       0.0
F   7        0.0       0.0       0.0       2.0
F   9        2.0       0.0       0.0       0.0
F  18            -1.0                0.0
THICK              .02,.04,0.05 /
TABLE    3  30.E6,30.E6,.3,11.5E6/
TABLE    2   10.E6,9.8E6,.3,3.8E6 /
TABLE    1   15.E6,15.E6,.3, 5.8E6 /
P   1  101   102     1          1
         .1      1.E7      1.E7         .3      3.E7
P   2  102   103     1          3     1
  (1,3,2/3,1,2)
P   3  103   104     1          1
         .1      1.E7      1.E7         .3      3.E7
P   4  102   105     1          1
         .1      1.E7      1.E7         .3      3.E7
P   5  105   106     2     0    2                                     -60.
         .1      1.E7      1.E7         .3      3.E7
 .05        30.  E6             .3       12.  E6
P   6  106   108     1     1    2     1
 (3,3/3,1)
P   7  107   108     1     1    1
         .1      1.E7      1.E7         .3      3.E7
P   9  108   109     1     1    1
         .1      1.E7      1.E7         .3      3.E7
P  10  109   110     2     0    1                                      15.
```

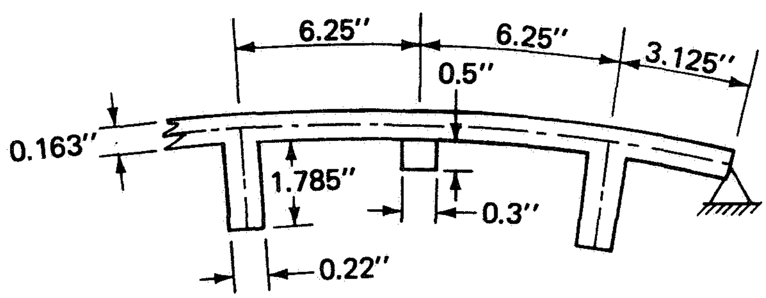
```
         .1       1.E7      1.E7        .3       3.E7
P  11  110  111     1         1
         .1       1.E7      1.E7        .3       3.E7
P  13  111  112     1         1
         .1       1.E7      1.E7        .3       3.E7
P  14  112  113     1         1
         .1       1.E7      1.E7        .3       3.E7
P  15  112  114     1         2    1
  (3,3/3,1)
P  17  114  115     1         1
         .1       1.E7      1.E7        .3       3.E7
P  18  116  117     1    1    2
         .1       1.E7      1.E7        .3       3.E7
         .3       1.E7      1.E7        .3       3.E7
B   8  108    1                                          0.5
      1.E7      3.E6        .1          .3       .01      .15      2.0      0.0
B  12  111    2    1
         .2       1.E7      3.E7        .5
B  16  114    3    3
        0.2       1.E7      3.E6
   0.25        15.  E7   3.5  E6
   0.3         30.  E6   12.  E6
L
```

8.2 Example 2: Curved Stiffened Panel

This example problem is illustrated in Figure 8.2. Rectangular beam elements (4) , (8) and (12) represent local skin reinforcements and the integral stiffeners are idealized with flat plate elements (2) , (6) , (10) and (14). The sides of the panel are simply supported. N_{11} critical load is sought for a constant transferse N_{22} load of 200 lbs./in.

This problem could be analyzed as a curved panel with repeated substructures. The use of this option could reduce this problem by several nodes and elements.





Midplane Radius = 198"
Panel Length = 50"
N_{22} = 200 lbs/in.

Material Data

Element	$E_{11}\times10^{-6}$ lbs/in^2	$E_{22}\times10^{-6}$ lbs/in^2	$G_{12}\times10^{-6}$ lbs/in^2	$G_{23}\times10^{-6}$ lbs/in^2	ν_{12}
Plate	10.5	10.5	3.975	—	0.32
Beam	30.0	—	—	0.8	—

Figure 8.2 Example No. 2 - Curved Stiffened Panel

```
   EXAMPLE NO.2   CURVED STIFFENED PANEL
    0    0    0    0    0    0    0
    0    1                                                        0
   13    3    4    8                    50.      200.
    1    2    1    3
N   1    1          -21.8305271.2071442
N   2    0           -19.7220   0.8871
N   3    3           -18.5548   2.6477
N   4    0           -12.4917   0.3944
N   5    0           - 6.2490   0.0986
N   6    3           - 6.1931   1.8663
N   7    0              0.0     0.0
N   8    0             6.2490   0.0986
N   9    3             6.1931   1.8663
N  10    0            12.4917   0.3944
N  11    0            18.7220   0.8871
N  12    3            18.5548   2.6477
N  13    1           21.8305271.2071442
E   4    4    7    7   10   10
D   3    1    6    7   10   11   13
F   3        0.0        0.0      .413      0.0
F   5        .413       0.0      0.0       0.0
F   7        0.0        0.0      .413      0.0
F   9        .413       0.0      0.0       0.0
F  11        0.0        0.0      .413      0.0
F  13        .413       0.0      0.0       0.0
P   1    1    2    2    0    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P   2    2    3    1    0    1         1   -0    0
  0.22      10.5 E6                .32     3.975 E6
P   3    2    4    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P   5    4    5    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P   6    5    6    1    0    1         1   -0    0
  0.22      10.5 E6                .32     3.975 E6
P   7    5    7    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P   9    7    8    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P  10    8    9    1    0    1         1   -0    0
  0.22      10.5 E6                .32     3.975 E6
P  11    8   10    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P  13   10   11    2    1    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
P  14   11   12    1    0    1         1   -0    0
  0.22      10.5 E6                .32     3.975 E6
P  15   11   13    2    0    1        -0   -0    0                198.
  0.163     10.5 E6                .32     3.975 E6
B   4    4    2    1                       -3.62
   .3       30. E6   8.   E6    .5
B   8    7    2    1                        0.0
   .3       30. E6   8.   E6    .5
B  12   10    2    1                       3.62
   .3       30. E6   8.   E6    .5
L
```

```
P R O G R A M   S G 3 3 7 A / BUCLASP2            OCT 26  72

BUCKLING LOADS OF LAMINATED STIFFENED PANELS

LOADING             -- IN-PLANE BIAXIAL

BOUNDARY CONDITIONS -- (1) SIMPLY SUPPORTED ALONG EDGES PARALLEL TO THE TRANSVERSE AXIS

                       (2) ELASTICALLY RESTRAINED ALONG ANY EDGE PARALLEL TO THE LONGITUDINAL AXIS

TYPES OF ELEMENTS   -- (1) FLAT PLATE

                       (2) CURVED PLATE

                       (3) BEAM

  EXAMPLE NO.2   CURVED STIFFENED PANEL
```

THIS IS AN EDITED EXAMPLE OF THE PROGRAM OUTPUT.

P R O G R A M   C O N T R O L   O P T I O N S

BUCKLING LOAD AND RELATIVE DISPLACEMENTS

NUMBER OF ITERATIONS ALLOWED IN BUCKLING CALCULATION = 100

NUMBER OF ITERATIONS USED IN EIGENVECTOR CALCULATION = 4

P R O B L E M   C H A R A C T E R I S T I C S

NUMBER OF NODES	=	13
NUMBER OF FLAT PLATE ELEMENTS	=	4
NUMBER OF CURVED PLATE ELEMENTS	=	8
NUMBER OF BEAM ELEMENTS	=	3
PANEL LENGTH	=	50.000
TRANSVERSE LOAD - N22	=	200.000

A N A L Y S I S   O P T I O N S

LOAD OPTION (LOADOP) = 1

WAVE NUMBER SEARCH OPTION (MOPT) = 2

INITIAL VALUE OF LONGITUDINAL WAVE NUMBER (MMI) = 1

FINAL VALUE OF LONGITUDINAL WAVE NUMBER (MMA) = 3

LOWER LIMIT FOR ROOT SEARCHING CRITERIA (NLW) = 0

UPPER LIMIT FOR ROOT SEARCHING CRITERIA (NUP) = 1

N O D A L   D A T A

NODE	COORDINATES Y	Z	BOUNDARY CONDITIONS CODE	SPRING STIFFNESSES K(W)	K(THETA)	K(V)	K(U)
1	-21.83053	1.20714	1				
2	-18.72200	.83710	0				
3	-18.55480	2.64770	3				
4	-12.49170	.39440	0				
5	-6.24900	.09860	0				
6	-6.19310	1.86630	3				
7	0.00000	0.00000	0				
8	6.24900	.09860	0				
9	6.19310	1.86630	3				
10	12.49170	.39440	0				
11	18.72200	.88710	0				
12	18.55480	2.64770	3				
13	21.83053	1.20714	1				

S U B S T R U C T U R E   D E F I N I T I O N   D A T A

NUMBER OF SUBSTRUCTURES = 3

SUBSTRUCTURE	FIRST NODE	LAST NODE
START	1	6
REPEAT	7	10
END	11	13

E Q U I V A L E N T   N O D E   D A T A

NODE I	NODE J
4	4
7	7
10	10

CURVED PLATE ELEMENT USER NUMBER 1 USER NODE I 1 USER NODE J 2 RADIUS = 198.00000

PLATE LOAD - N22 = 200.000

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS = 5

MATERIAL PROPERTY INPUT OPTION = 0

MATERIAL PROPERTY INPUT FORMAT OPTION = -0

LAYER	THICKNESS	EXX	EYY	NUXY	NUYX	G
1	1.630000E-01	1.050000E+07	1.050000E+07	3.200000E-01	3.200000E-01	3.975000E+06

8.11

A-MATRIX

1906751.337	610160.428	0.000
610160.428	1906751.337	0.000
0.000	0.000	647925.000

B-MATRIX

0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000

D-MATRIX

4221.706	1350.946	0.000
1350.946	4221.706	0.000
0.000	0.000	1434.560

FLAT PLATE ELEMENT USER NUMBER 2 USER NODE I 2 USER NODE J 3

PLATE LOAD - N22 = 0.000

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS = 5

MATERIAL PROPERTY INPUT OPTION = 0

MATERIAL PROPERTY INPUT FORMAT OPTION = -0

LAYER	THICKNESS	EXX	EYY	NUXY	NUYX	G
1	2.200000E-01	1.050000E+07	1.050000E+07	3.200000E-01	3.200000E-01	3.975000E+06

A-MATRIX

2573529.412	823529.412	0.000
823529.412	2573529.412	0.000
0.000	0.000	874500.000

B-MATRIX

-.000	-.000	0.000
-.000	-.000	0.000
0.000	0.000	-.000

D-MATRIX

10379.902	3321.569	0.000
3321.569	10379.902	0.000
0.000	0.000	3527.150

```
BEAM ELEMENT   USER NUMBER      4       USER NODE      4

MATERIAL PROPERTY INPUT FORMAT OPTION          =     -0

OPTION          2
RECTANGULAR BEAM ELEMENT



BEAM ELEMENT DIMENSIONS

WIDTH      WB=                 .5000

THICKNESS TB=                  .3000


BEAM ELEMENT PROPERTIES
FOR LAMINATED BEAM ELEMENTS THE  PROPERTIES ARE GIVEN FOR ALL LAMINAS


AREA                      AFA =          1.5000E-01
MOM. OF INERTIA           RYY =          3.1250E-03
MOM. OF INERTIA           RZZ =          1.1250E-03
POLAR MOM. OF INERTIA RIP =              4.2500E-03
WARPING CONSTANT          GAM =          2.3438E-05
TORSION CONSTANT           RJ =          2.8174E-03
E-MODULUS                 EXX =          3.0000E+07
G-MODULUS                 GBA =          8.0000E+06
Y DISTANCE                 YN =         -8.8818E-16
Z DISTANCE                 ZN =          0.
```

P L A T E   E L E M E N T   I N P U T   O F F S E T S

ELEM.	START ZO	START YO	END ZO	END YO
3	0.00000	0.00000	.41300	0.00000
5	.41300	0.00000	0.00000	0.00000
7	0.00000	0.00000	.41300	0.00000
9	.41300	0.00000	0.00000	0.00000
11	0.00000	0.00000	.41300	0.00000
13	.41300	0.00000	0.00000	0.00000

P L A T E   E L E M E N T   N E T   O F F S E T S

ELEM. NO.	START ZO	START YO	END ZO	END YO
1	0.00000	0.00000	0.00000	0.00000
2	0.00000	0.00000	0.00000	0.00000
3	0.00000	0.00000	.33150	0.00000
5	.33150	0.00000	0.00000	0.00000
6	0.00000	0.00000	0.00000	0.00000
7	0.00000	0.00000	.33150	0.00000
9	.33150	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000	0.00000
11	0.00000	0.00000	.33150	0.00000
13	.33150	0.00000	0.00000	0.00000
14	0.00000	0.00000	0.00000	0.00000
15	0.00000	0.00000	0.00000	0.00000

E L E M E N T   T R A N S F O R M A T I O N   D A T A

ELEM. NO.	WIDTH	TRANSFORMATION SIN(I)	COS(I)	SIN(J)	COS(J)	EL.TYPE
1	3.12499	-.11026	.99390	-.09455	.99552	CRVD PLATE
2	1.76852	.99552	.09454	.99552	.09454	FLAT PLATE
3	6.25001	-.09456	.99552	-.06309	.99801	CRVD PLATE
4	6.24996	-.06309	.99801	-.03156	.99950	CRVD PLATE
5	1.76858	.99950	.03161	.99950	.03161	FLAT PLATE
6	6.25004	-.03155	.99950	.00001	1.00000	CRVD PLATE
7	6.25004	-.00001	1.00000	.03155	.99950	CRVD PLATE
8	1.76858	.99950	-.03161	.99950	-.03161	FLAT PLATE
9	6.24996	.03156	.99950	.06309	.99801	CRVD PLATE
10	6.25001	.06309	.99801	.09456	.99552	CRVD PLATE
11	1.76852	.99552	-.09454	.99552	-.09454	FLAT PLATE
12	3.12499	.09456	.99552	.11026	.99390	CRVD PLATE
1		0.00000	1.00000			BEAM
2		0.00000	1.00000			BEAM
3		.06314	.99800			BEAM

E L E M E N T   S U B S T R U C T U R E   A S S I G N M E N T   D A T A

NUMBER	BLOCK
1	START
2	START
3	START
4	START
5	START
6	REPEAT
7	REPEAT
8	REPEAT
9	REPEAT
10	END
11	END

12	END
1	START
2	REPEAT
3	REPEAT

```
****************************************************


ASSUMING A PROGRAM LENGTH OF       0000050000   OCTAL

(EXCLUDING BLANK COMMON)


FOR LOAD CALCULATION THE
RECOMMENDED FIELD LENGTH IS        0000051430   OCTAL

FOR EIGENVECTOR CALCULATION THE
RECOMMENDED FIELD LENGTH IS        0000052314   OCTAL


****************************************************
```

```
******************************
*                            *
*    MODE   IS   M =    1    *
*                            *
*                            *
******************************
```

EXAMPLE NO.2 CURVED STIFFENED PANEL

PANEL UPPER BOUND = 3.4521E+05 (ELEMENT 6)

VARIABLE LOAD ON FIRST PLATE ELEMENT	NUMBER OF NEG. ON DIAGONAL	BUCKLING DETERMINANT (A*(2**B)) A	B	COMMENTS
172602.9719	9	-.50675	420	
86301.48597	8	.24295	412	
43150.74298	7	-.95983	404	
21575.37149	6	.93331	392	
10787.68575	5	-.48272	392	
5393.842873	4	.12240	392	
2696.921436	3	-.32735	388	
1348.460718	2	.85340	384	
674.2303591	1	-.13539	384	
337.1151796	0	.09735	388	
505.6727693	0	.30105	384	
589.9515642	0	.50746	376	
632.0909617	1	-.08445	384	
611.0212629	1	-.73550	380	
600.4864136	1	-.37144	380	
595.2189889	1	-.17482	380	
592.5852766	1	-.07280	380	
591.2684204	1	-.33373	376	
590.6099923	0	.08561	376	
590.9392064	1	-.12437	376	
590.7745993	1	-.31138	372	
590.6922958	0	.52886	372	
590.7334476	0	.10866	372	
590.7540235	1	-.10138	372	
590.7437355	0	.93021	364	
590.7488795	1	-.78201	368	
590.7463075	1	-.36194	368	
590.7450215	1	-.15189	368	
590.7443785	1	-.75020	364	
590.7440570	0	.09010	364	
590.7442178	1	-.33036	364	
590.7441374	1	-.11967	364	
590.7440972	1	-.24434	360	
590.7440771	0	.60997	360	
590.7440872	0	.17758	360	
590.7440922	1	-.57048	356	
590.7440897	0	.07321	360	
590.7440909	0	.38524	356	

E L E M E N T   L O A D S

ELEM. NO.	N11	N22	EPS11	EPS22	F-BEAM	ELEMENT TYPE
1	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
2	710.94294	0.	3.07767509E-04	-9.84856027E-05		FLAT PLATE
3	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
4	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
5	710.94294	0.	3.07767509E-04	-9.84856027E-05		FLAT PLATE
6	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
7	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
8	710.94294	0.	3.07767509E-04	-9.84856027E-05		FLAT PLATE
9	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
10	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
11	710.94294	0.	3.07767509E-04	-9.84856027E-05		FLAT PLATE
12	590.74409	200.00000	3.07767509E-04	6.40484423E-06		CRVD PLATE
13			3.07767509E-04		1384.9538	BEAM EL.
14			3.07767509E-04		1384.9538	BEAM EL.
15			3.07767509E-04		1384.9538	BEAM EL.

T O T A L   L O A D   A T   B U C K L I N G

AXIAL = 3.503E+04

TRANSVERSE = 1.000E+04

EXAMPLE NO.2 CURVED STIFFENED PANEL

B U C K L I N G   L O A D   C O M P U T A T I O N   S U M M A R Y

CRITICAL WAVE NUMBER M = 1

M	LOAD
1	590.7440922
2	1660.160301
3	2485.235669

EXAMPLE NO.2 CURVED STIFFENED PANEL

```
******************************
*        EIGENVECTOR         *
*            AND             *
*   RELATIVE DISPLACEMENTS   *
******************************
*                            *
*         M =      1         *
*                            *
******************************
```

STIFFNESS MATRIX BANDWIDTH = 9

EIGENVECTOR

ITERATION NUMBER 1
NORMALIZING FACTOR 6.3592998E+04

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	4.48993080E-01	1.36031383E-01	9.86112995E-03	6.25483218E-03
	4	1.00000000E+00	1.45899131E-02	5.16335990E-02	-8.34836046E-03
	5	6.52239149E-01	-9.70813322E-02	4.30934805E-02	1.04170279E-02
REPEAT	7	3.56400531E-05	-1.06982690E-01	6.89987954E-02	2.56778098E-05
	8	-6.51228758E-01	-9.69334261E-02	4.30682008E-02	-1.03561897E-02
	10	-9.98609014E-01	1.45467582E-02	5.16106616E-02	8.37423585E-03
END	11	-4.48032545E-01	1.35777756E-01	9.86467526E-03	-6.17523334E-03

EIGENVECTOR

ITERATION NUMBER 2
NORMALIZING FACTOR 3.4229813E+07

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	-4.48796704E-01	-1.36007908E-01	-9.87724972E-03	-6.18252389E-03
	4	-1.00000000E+00	-1.45593499E-02	-5.16734615E-02	8.37220152E-03
	5	-6.52157087E-01	9.70601762E-02	-4.31174909E-02	-1.03953037E-02
REPEAT	7	1.39570859E-04	1.07097991E-01	-6.90690919E-02	-1.66525093E-06
	8	6.52229265E-01	9.70060349E-02	-4.31129653E-02	1.03963669E-02
	10	9.99776003E-01	-1.45867119E-02	-5.16461913E-02	-8.36885938E-03
END	11	4.48649627E-01	-1.35966246E-01	-9.86658961E-03	5.18128460E-03

EIGENVECTOR

ITERATION NUMBER 3
NORMALIZING FACTOR 3.4250420E+07

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	4.48796704E-01	1.36007908E-01	9.87724972E-03	6.18252389E-03
	4	1.00000000E+00	1.45593499E-02	5.16734615E-02	-8.37220152E-03
	5	6.52157087E-01	-9.70601762E-02	4.31174909E-02	1.03953027E-02
REPEAT	7	-1.39570860E-04	-1.07097991E-01	6.90690919E-02	1.66525095E-06

	8	-6.52229265E-01	-9.70060349E-02	4.31129653E-02	-1.03963669E-02
	10	-9.99776003E-01	1.45867119E-02	5.16461913E-02	8.36885938E-03
END	11	-4.48649627E-01	1.35966246E-01	9.86658961E-03	-6.18128480E-03

EIGENVECTOR

ITERATION NUMBER 4
NORMALIZING FACTOR 3.4250420E+07

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	-4.48796704E-01	-1.36007908E-01	-9.87724972E-03	-6.18252389E-03
	4	-1.00000000E+00	-1.45593499E-02	-5.16734615E-02	8.37220152E-03
	5	-6.52157087E-01	9.70601762E-02	-4.31174909E-02	-1.03953037E-02
REPEAT	7	1.39570860E-04	1.07097991E-01	-6.90690919E-02	-1.66525095E-06
	8	6.52229265E-01	9.70060349E-02	-4.31129653E-02	1.03963669E-02
	10	9.99776003E-01	-1.45867119E-02	-5.16461913E-02	-8.36885938E-03
END	11	4.48649627E-01	-1.35966246E-01	-9.86658961E-03	6.18128480E-03

EXAMPLE NO.2 CURVED STIFFENED PANEL

```
********************************
*                              *
*   RELATIVE DISPLACEMENTS     *
*                              *
********************************
*                              *
*         M =      1           *
*                              *
********************************
```

START SECTION --BLOCK NO. 1

ELEMENT NO.= 1 TYPE = CRVD PLATE NODE I = 1 NODE J = 2 WIDTH = 3.1250

Y	W	V	THETA
-1.5625	-.00000	.03636	-.14676
-.7812	-.11461	.03612	-.14605
.0000	-.22813	.03541	-.14396
.7812	-.33948	.03424	-.14056
1.5625	-.44772	.03261	-.13601

ELEMENT NO.= 2 TYPE = FLAT PLATE NODE I = 2 NODE J = 3 WIDTH = 1.7685

Y	W	V	THETA
-.8843	-.03260	-.44772	-.13601
-.4421	-.09263	-.44772	-.13557
0.0000	-.15250	-.44761	-.13530
.4421	-.21230	-.44739	-.13520
.8843	-.27208	-.44706	-.13526

ELEMENT NO.= 3 TYPE = CRVD PLATE NODE I = 2 NODE J = 4 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	-.44772	.03260	-.13601
-1.5625	-.65203	.02806	-.12262
.0000	-.82402	.02198	-.09521
1.5625	-.94453	.01471	-.05753
3.1250	-1.00127	.00670	-.01456

ELEMENT NO.= 5 TYPE = CRVD PLATE NODE I = 4 NODE J = 5 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	-1.00127	.00669	-.01456
-1.5625	-.99079	-.00151	.02739
0.0000	-.91896	-.00939	.06301
1.5625	-.79959	-.01649	.08744
3.1250	-.65319	-.02251	.09706

ELEMENT NO.= 6 TYPE = FLAT PLATE NODE I = 5 NODE J = 6 WIDTH = 1.7686

Y	W	V	THETA
-.8843	.02248	-.65319	.09706
-.4421	.06532	-.65320	.09675
0.0000	.10806	-.65305	.09656
.4421	.15073	-.65275	.09648
.8843	.19339	-.65228	.09653

ELEMENT NO.= 4 TYPE = BEAM EL. NODE = 4

W	V	THETA
-1.00000	-.05167	-.01456

REPETITIVE SECTION --BLOCK NO. 2

ELEMENT NO.= 7 TYPE = CRVD PLATE NODE I = 5 NODE J = 7 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	-.65319	-.02252	.09706
-1.5625	-.49764	-.02731	.10175
0.0000	-.33523	-.03078	.10559
1.5625	-.16816	-.03287	.10756
3.1250	.00014	-.03357	.10710

ELEMENT NO.= 9 TYPE = CRVD PLATE NODE I = 7 NODE J = 8 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	.00014	-.03357	.10710
-1.5625	.16843	-.03287	.10754
0.0000	.33545	-.03077	.10556
1.5625	.49779	-.02730	.10171
3.1250	.65326	-.02251	.09701

ELEMENT NO.= 10 TYPE = FLAT PLATE NODE I = 8 NODE J = 9 WIDTH = 1.7686

Y	W	V	THETA
-.8843	.02248	.65327	.09701
-.4421	.06529	.65327	.09670
0.0000	.10800	.65313	.09650
.4421	.15065	.65282	.09643
.8843	.19329	.65235	.09647

ELEMENT NO.= 11 TYPE = CRVD PLATE NODE I = 8 NODE J = 10 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	.65327	-.02251	.09701
-1.5625	.79958	-.01648	.08739
0.0000	.91886	-.00938	.06295
1.5625	.99062	-.00151	.02735
3.1250	1.00104	.00670	-.01459

ELEMENT NO.= 8 TYPE = BEAM EL. NODE = 7

W	V	THETA
.00014	-.06907	.10710

ELEMENT NO.= 12 TYPE = BEAM EL. NODE = 10

W	V	THETA
1.00104	.01158	-.01459

END SECTION --BLOCK NO. 3

ELEMENT NO.= 13 TYPE = CRVD PLATE NODE I = 10 NODE J = 11 WIDTH = 6.2500

Y	W	V	THETA
-3.1250	1.00104	.00670	-.01459
-1.5625	.94427	.01471	-.05754
.0000	.82377	.02198	-.09519
1.5625	.65182	.02806	-.12259
3.1250	.44757	.03260	-.13597

ELEMENT NO.= 14 TYPE = FLAT PLATE NODE I = 11 NODE J = 12 WIDTH = 1.7685

Y	W	V	THETA
-.8843	.01012	.14726	-.04000
-.4421	-.00754	.14723	-.03987
0.0000	-.02515	.14716	-.03979
.4421	-.04273	.14706	-.03975
.8843	-.06030	.14692	-.03976

ELEMENT NO.= 15 TYPE = CRVD PLATE NODE I = 11 NODE J = 13 WIDTH = 3.1250

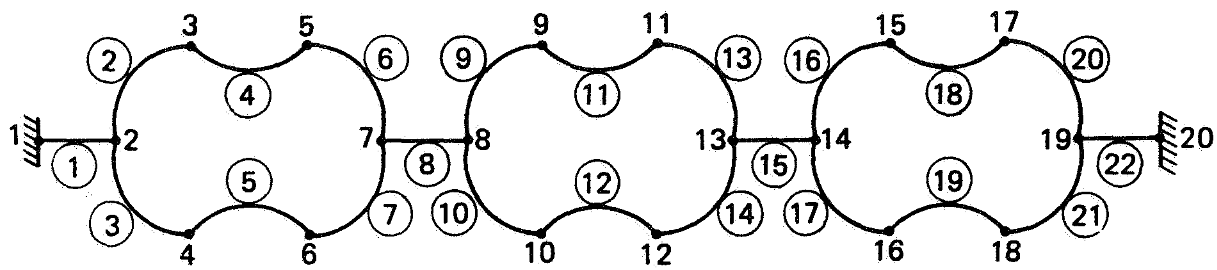
Y	W	V	THETA
-1.5625	.14726	-.01686	-.04000
-.7812	.11421	-.01629	-.04459
.0000	.07600	-.01587	-.04807
.7812	.03957	-.01562	-.05024
1.5625	-.00000	-.01553	-.05098

T I M I N G   S U M M A R Y

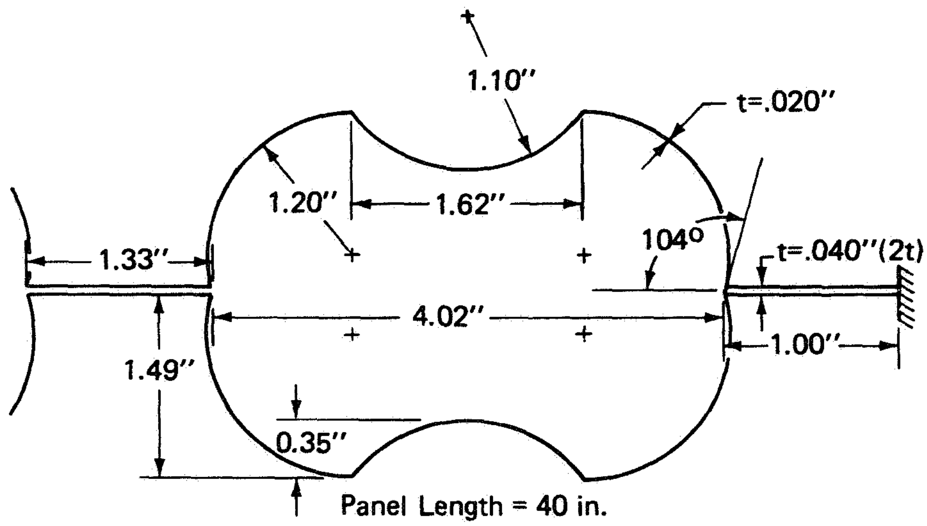
FUNCTION	CP TIME	PER CENT OF TOTAL
DATA PROCESSING	.77	.009
UPPER BOUND CALCULATION	14.04	.158
STIFFNESS GENERATION	71.90	.808
DETERMINANT CALCULATION	1.61	.018
ELEMENT DISPLACEMENTS	.63	.007

8.3 Example 3: Advanced Structural Panel

The geometry and idealization for the panel is shown in Figure 8.3. The user should pay particular attention to the signs of the radii of curvatures of the curved plate elements.



Idealization



Geometry

Material Properties

E	(lbs/in^2)	10.5×10^6
ν		0.32
G	(lbs/in^2)	3.975×10^6

Figure 8.3 Example No. 3 - Advanced Structural Panel

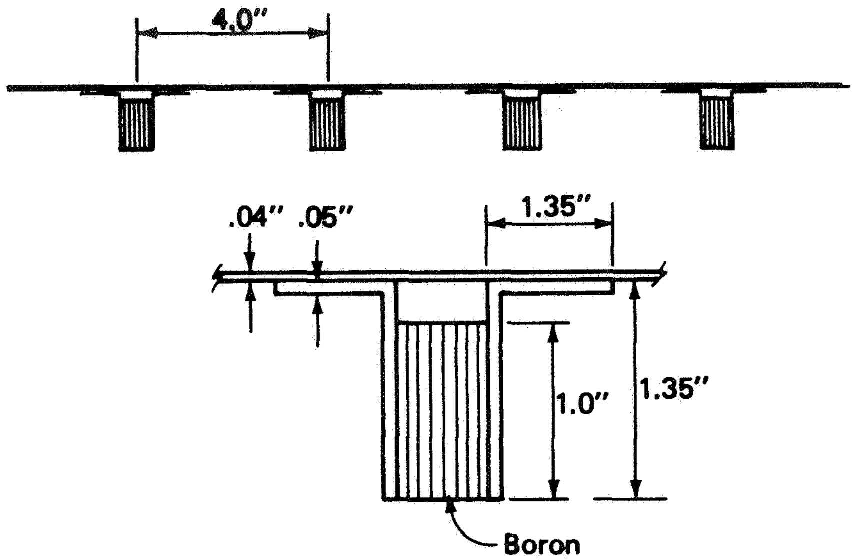
```
     EXAMPLE NO.3   ADVANCED STRUCTURAL PANEL
     0    0    0    0    0    0    0
     0    1                                                              0
    20    0    4   18                      120.0
     1    2    2    4                             5000.0
N    1    4           -8.36     0.0
N    2    0           -7.36     0.0
N    3    0           -6.16    -1.49
N    4    0           -6.16     1.49
N    5    0           -4.54    -1.49
N    6    0           -4.54     1.49
N    7    0           -3.34     0.0
N    8    0           -2.01     0.0
N    9    0            -.81    -1.49
N   10    0            -.81     1.49
N   11    0             .81    -1.49
N   12    0             .81    1.49
N   13    0            2.01     0.0
N   14    0            3.34     0.0
N   15    0            4.54    -1.49
N   16    0            4.54     1.49
N   17    0            6.16    -1.49
N   18    0            6.16     1.49
N   19    0            7.36     0.0
N   20    4            8.36     0.0
D    3    1    7    8   13   14   20
S    1        1.  E100  1.  E100  1.  E100
S   20        1.  E100   1. E100  1.  E100
P    1    1    2    1    0    1       -0    -0   -0
     .040   10.3 E6   10.3E6   .33    3.87 E6
P    2    2    3    2    0    1       -0    -0   -0                  1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    3    2    4    2    0    1       -0    -0   -0                 -1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    4    3    5    2    0    1       -0    -0    0                 -1.10
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    5    4    6    2    0    1       -0    -0    0                  1.10
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    6    5    7    2    0    1       -0    -0   -0                  1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    7    6    7    2    0    1       -0    -0    0                 -1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P    8    7    8    1    0    1       -0    -0   -0
     .040   10.3 E6   10.3E6   .33    3.87 E6
P    9    8    9    2    0    1       -0    -0   -0                  1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   10    8   10    2    0    1       -0    -0    0                 -1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   11    9   11    2    0    1       -0    -0    0                 -1.10
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   12   10   12    2    0    1       -0    -0   -0                  1.10
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   13   11   13    2    0    1       -0    -0    0                  1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   14   12   13    2    0    1       -0    -0    0                 -1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   15   13   14    1    0    1       -0    -0    0
     .040   10.3 E6   10.3E6   .33    3.87 E6
P   16   14   15    2    0    1       -0    -0    0                  1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
P   17   14   16    2    0    1       -0    -0    0                 -1.20
     .020   10.3 E6   10.3E6   .33    3.87 E6
```

```
P  10   15   17    2    0    1       -0   -0    0                    -1.10
      .020    10.3 E6    10.3E6    .33       3.87 E6
P  19   16   18    2    0    1       -0   -0    0                     1.10
      .020    10.3 E6    10.3E6    .33       3.87 E6
P  20   17   19    2    0    1       -0   -0    0                     1.20
      .020    10.3 E6    10.3E6    .33       3.87 E6
P  21   18   19    2    0    1       -0   -0    0                    -1.20
      .020    10.3 E6    10.3E6    .33       3.87 E6
P  22   19   20    1    0    1       -0   -0    0
      .040    10.3 E6    10.3E6    .33       3.87 E6
L
```

8.4 Example 4: Flat Stiffened Panel

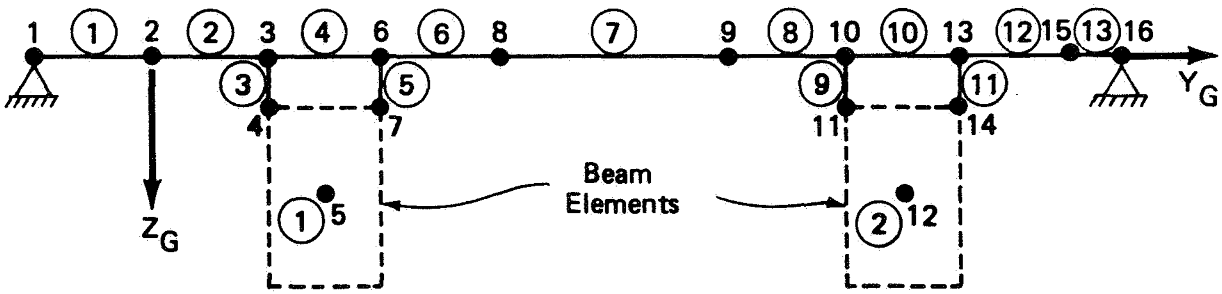
Figure 8.4 contains the pertinent data for an angle stiffened, bonded titanium panel with local boron reinforcements on the stiffeners. The Y_G axis passes through the midplane of element (2), which is idealized as three bonded layers, skin, adhesive and stiffener flange. The boron reinforcements, beam elements (1) and (2), are idealized with 15 layers each. The boron reinforcement is actually simulated with six layers and the layers are separated by non-structural elements to retain the correct lamina geometry including the adhesive thicknesses. This representation should give the proper stiffnesses for the boron reinforcement.

Use is made of the flat panel repeat substructure option to minimize the input and also the computer costs.



Stiffened Panel (Length = 33.7")

Adhesive Layer = .005"



Idealization

Material Properties

Material	$E_{11} \times 10^{-6}$ (lbs/in^2)	$E_{22} \times 10^{-6}$ (lbs/in^2)	ν_{12}	$G_{12} \times 10^{-6}$ (lbs/in^2)
Aluminum	10.5	10.5	0.3	4.05
Boron	29.117	2.341	0.2467	0.75

Figure 8.4 Example No. 4 – Flat Stiffened Panel

```
    EXAMPLE NO.4    STIFFENED TITANIUM PANEL
    0    0    0    0    0    0    0
    0    1                                                                  0
   16    2   13    0                             33.7
    1    2   13   13
N   1    1                 -0.1      0.0
N   2    0                  0.0      0.0
N   3    0                1.325      0.0
N   4    0                1.325    .3425
N   5    0                1.471    .8425
N   6    0                1.617      0.0
N   7    0                1.617    .3425
N   8    0                2.942      0.0
N   9    0                  4.0      0.0
N  10    0                5.325      0.0
N  11    0                5.325    .3425
N  12    0                5.471    .8425
N  13    0                5.617      0.0
N  14    0                5.617    .3425
N  15    0                6.942      0.0
N  16    1                7.042      0.0
E   5    4    7    4   12   11   14   11
D   6    1    7    8   14   15   16
C   6   13
F   1         .0475                .0475
F   4         .0475                .0475
F   7         .0475                .0475
F  10         .0475                .0475
F  13         .0475                .0475
F   3                              -.121        .5
F   9                              -.121        .5
F   5                               .171        .5
F  11                               .171        .5
P   1    1    2    1    1    1        -0   -0   -0
       .040   10.5+6                  .3   4.05+6
P   2    2    3    1    0    3        -0   -0   -0
       .040   10.5+6                  .3   4.05+6
       .005
       .050   10.5+6                  .3   4.05+6
P   3    3    4    1    1    1        -0   -0   -0
       .050   10.5+6                  .3   4.05+6
P   4    3    6    1    1    1        -0   -0    0
       .040   10.5+6                  .3   4.05+6
P   5    6    7    1    1    1        -0   -0    0
       .050   10.5+6                  .3   4.05+6
P   6    6    8    1    0    3        -0   -0   -0
       .040   10.5+6                  .3   4.05+6
       .005
       .050   10.5+6                  .3   4.05+6
P   7    8    9    1    1    1        -0   -0    0
       .040   10.5+6                  .3   4.05+6
P   8    9   10    1    0    3        -0   -0   -0
       .040   10.5+6                  .3   4.05+6
       .005
       .050   10.5+6                  .3   4.05+6
P   9   10   11    1    1    1        -0   -0   -0
       .050   10.5+6                  .3   4.05+6
P  10   10   13    1    1    1        -0   -0    0
       .040   10.5+6                  .3   4.05+6
P  11   13   14    1    1    1        -0   -0    0
       .050   10.5+6                  .3   4.05+6
P  12   13   15    1    0    3        -0   -0   -0
```

```
          .040     10.5+6                        .3     4.05+6
          .005
          .050     10.5+6                        .3     4.05+6
P   13     15     16     1      1     1          -0    -0     0
          .040     10.5+6                        .3     4.05+6
B    1      5      2    15                                 0.0
           .05     10.5+6     4.05+6             1.
          .013
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .021
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .021
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .013
           .05     10.5+6     4.05+6
B    2     12      2    15                                 0.0
           .05     10.5+6     4.05+6             1.
          .013
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .021
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .021
         .0275   29.117+6    00.75+6
          .003
         .0275   29.117+6    00.75+6
          .013
           .05     10.5+6     4.05+6
L
```

9.0 PROGRAM DESCRIPTION

This section is a description of the organization and function of the various routines included in BUCLASP2.

9.1 Overlay Structure

BUCLASP2 consists of a (0,0) level overlay which acts as a monitor in selection of primary overlays. Each primary overlay performs a discrete logical step in the analysis. The overlay structure is:

(1) (0,0) Overlay

- (a) BUCLASP,0,0 — SO337A, Monitor

(2) Primary Overlays

- (a) BUCLASP,1,0 — DATAPRO, Reads all user input and outputs basic job description
- (b) BUCLASP,2,0 — LOADING, Generates element stiffness, merges panel stiffness matrix, controls calculation of buckling load and calculates determinant of panel stiffness matrix
- (c) BUCLASP,3,0 — DISPLAC, Calculates for buckling load panel eigenvector and element relative displacements

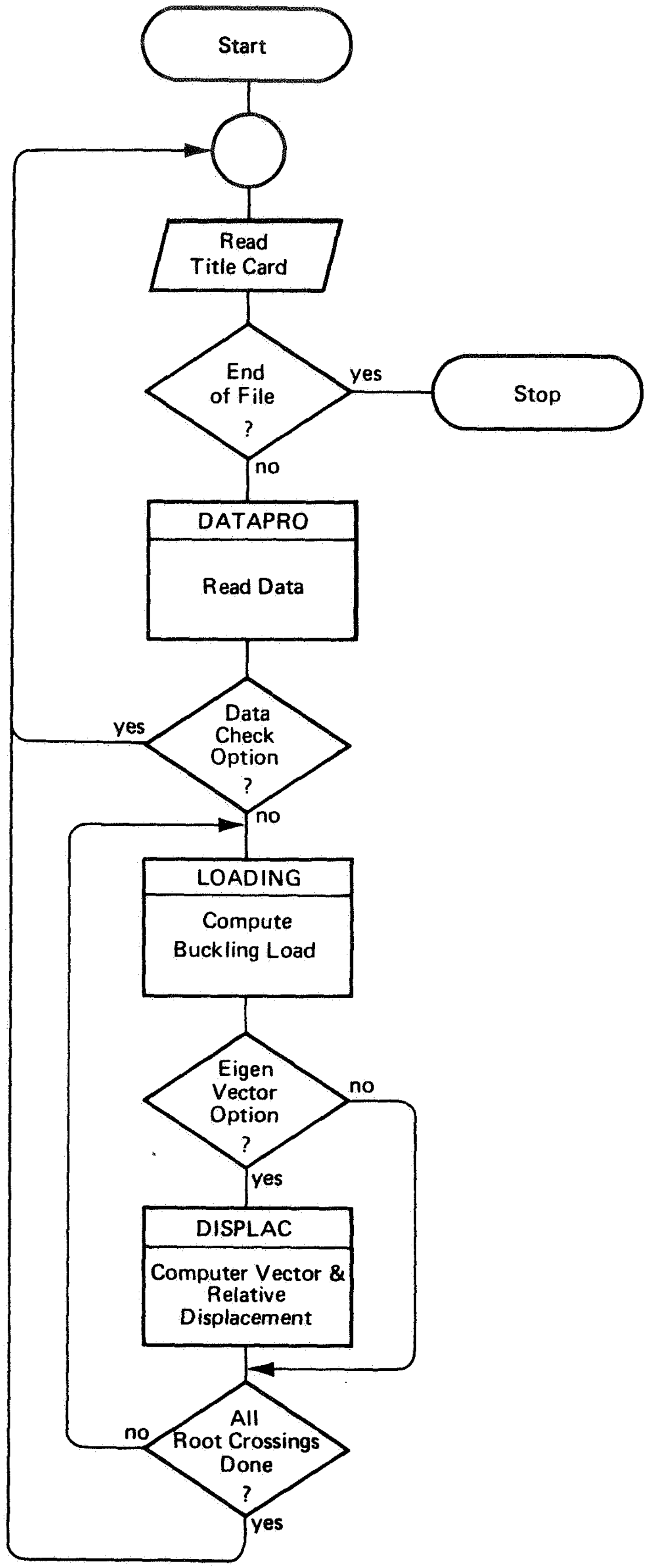
Main Overlay 0.0

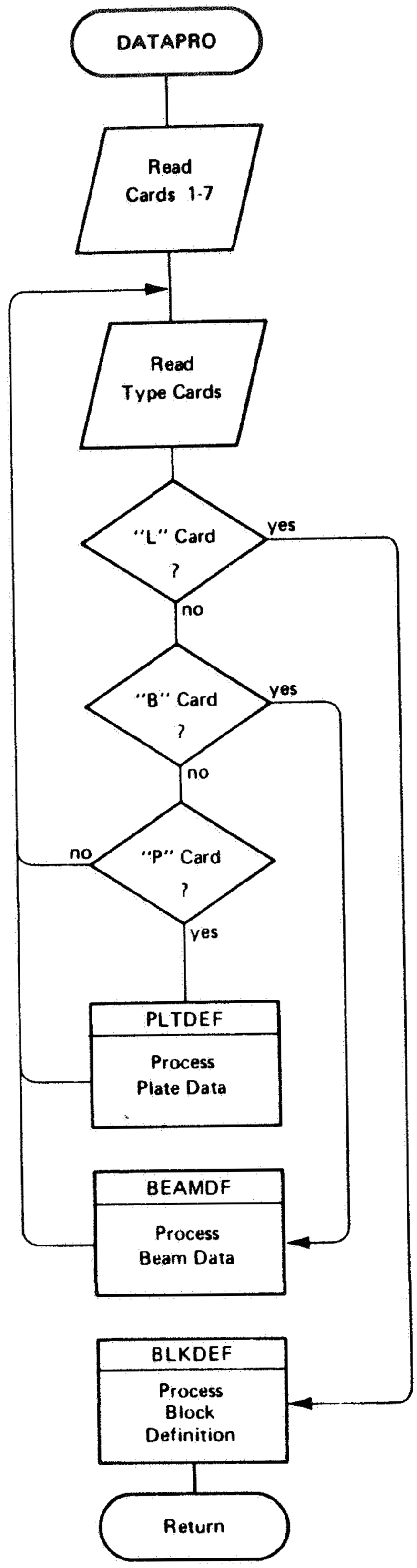
Program Name: S0337A

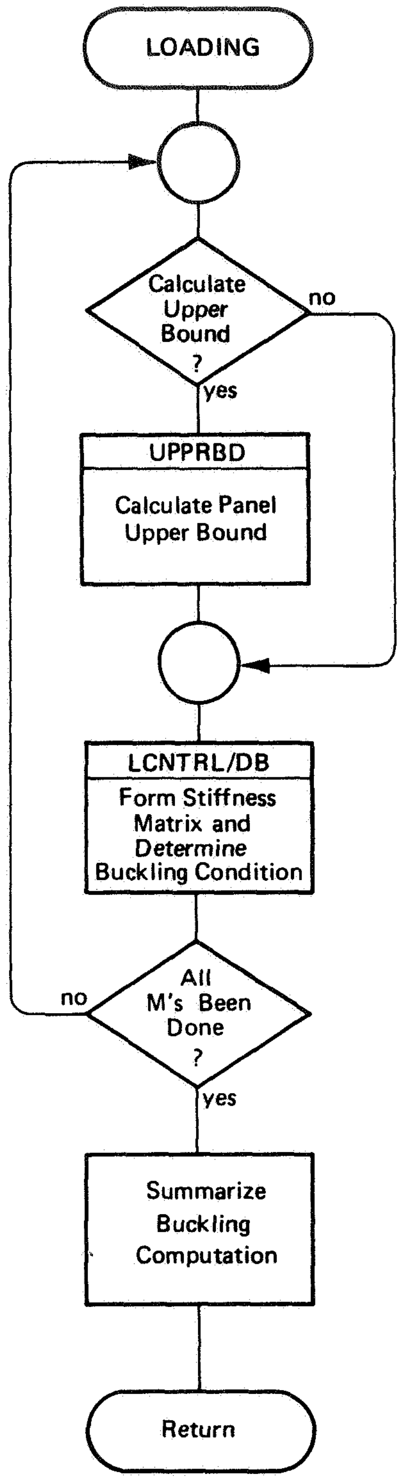
Subroutines: ERROR
PRINT
IGAL
PAC
UNPAC

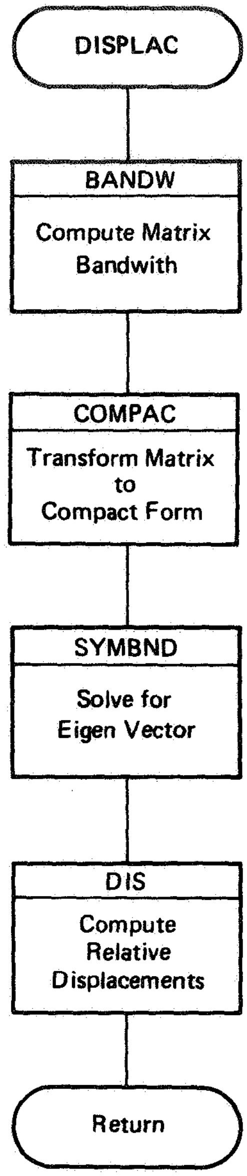
Primary Overlay 1.0	Primary Overlay 2.0	Primary Overlay 3.0
Main Prog: DATAPRO	Main Prog: LOADING	Main Prog: DISPLAC
Subroutines: RDVLS BEAMDF USERID BLKDEF PLTDEF TBPOINT NEXTC FINDIN CLNODE RDTBLE IBLKNO STRMOV	Subroutines: LCNTRL DM UPPRBD GAPUPP TRANF SBLKDT BLKGEN SELIM REDUVE DBLERT STORE PRDMTX PROOT FPLATE FPLCOL BEAM SOLVE DT RGEN CDTM VIPDR ZARK MATZ TRANSF EVALUE	Subroutines: BANDW COMPAC BLKGEN SYMBND REDUVE DIS FETCHD READTR FNLDIS TRANW TRAN1 FANGLE

9.2 Basic Program Flow




DATAPRO
Read
Cards 1-7
Read
Type Cards
"L" Card
?
yes
no
"B" Card
?
yes
no
"P" Card
?
no
yes
PLTDEF
Process
Plate Data
BEAMDF
Process
Beam Data
BLKDEF
Process
Block
Definition
Return


LOADING
Calculate Upper Bound ?
no
yes
UPPRBD
Calculate Panel Upper Bound
LCNTRL/DB
Form Stiffness Matrix and Determine Buckling Condition
All M's Been Done ?
no
yes
Summarize Buckling Computation
Return


DISPLAC
BANDW
Compute Matrix Bandwith
COMPAC
Transform Matrix to Compact Form
SYMBND
Solve for Eigen Vector
DIS
Compute Relative Displacements
Return

9.3 Program/Subroutine Description

ROUTINE	PURPOSE	CONFIGURATIONS	TESTS
BANDW	BANDW calculates bandwidth of the panel stiffness matrix for COMPAC.	Panel with	
		1) Start substructure only	F-1
		2) Start and End substructures only	F-8
		3) Start, Repeat and End substructures	F-8
			F-22
BEAM	BEAM generates beam element displacement, force and stiffness matrices.	1. Beam element is input at an angle.	F-23
		2. Beam element is input with offsets.	F-39
BEAMDF	BEAMDF reads and processes beam material properties.	1. General beam element	F-25
		2. Rectangular beam with	
		a) one lamina	F-24
		b) more than one lamina	F-23
		3. Circular beam with	
		a) one lamina	F-39
		b) more than one lamina	F-26
		4. Laminated beam input by	
		a) B-i cards	F-23
		b) Tables	F-39

ROUTINE	PURPOSE	CONFIGURATIONS	TESTS
BLKDEF	BLKDEF processes block definition node pairs to produce the row and column definition for each block and the produce the corresponding merging information.	1. Problem with	
		a) with equivalent nodes	F-23
		b) without equivalent nodes	F-22
		c) start substructure only	F-1
		d) start and end substructures only	F-38
		e) start, repeat and end substructures	F-22
		f) beam elements	F-23
BLKGEN	In the curved panel option, BLKGEN transforms a Repeat or End substructure of the panel stiffness matrix from its initial global position to its final global position.	1. The initial substructure is read from a binary file.	F-10
		2. The initial substructure is assumed to be in core.	F-10
CDTM	CDTM evaluates the determinant of a complex square matrix.		F-1
CLNODE	For each node between the first node and the last node of a block definition pair, investigate the elements having the node as a definition node, from those elements find the smallest and largest internal node number.	1. Plates only	F-1
		2. Plates and Beams	F-23

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
COMPAC	COMPAC takes the panel stiffness matrix as generated in the buckling computation and puts it inot symmetric band format suitable for eigenvector computation with all repeat substructures present.	Panel with	
		a) Start substructure only	F-1
		b) Start and End substructures only	F-38
		c) Start, Repeat and End substructures	F-22
		d) Start, Repeat and End substructures in curved panel option	F-10
DATAPRO	DATAPRO reads input cards 1-6, cards T,C,E,D,N,S,P,B,F and L and processes the corresponding data. The remaining data processing routines are called as required.	Problem with	
		1. Start substructure only	F-1
		2. Start and End substructures only	F-38
		3. Start, Repeat and End substructures	F-22
		4. T cards	F-39
		5. C cards	F-23
		6. E cards	F-23
		7. D cards	F-23
		8. N cards	F-23
		9. S cards	F-23
		10. B cards	F-23
		11. P cards	F-23
		12. F cards	F-22
		13. L cards	F-22
		14. Beam element	F-23
		15. Flat Plate element	F-23
		16. Curved Plate element	F-21
		User Diagnostics	F-40 - F-90

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
DB	DB forms and evaluates the buckling determinant for a given load and way number M.	1. Problem with	
		a) N_{11} varying	F-11
		b) N_{11} varying with biaxial ratio	F-15
		c) N_{22} varying	F-28
		d) N_{22} with constant strain	F-19
		2. Problem with	
		a) Clamped Node	F-2
		b) Simply supported Node	F-1
		c) Free Node	F-1
		d) Sprung Node	F-11
		3. Problem with Plates & Beams	F-23
		4. Problem with Curved Panel Option	F-11
DBLERT	DBLERT is the error trap routine for PROOT encountering a double root.		Inspection
DIS	DIS computes the relative displacements of the deformed panel.	1. Panel with	
		a) Start substructure only	F-1
		b) Start and End substructures only	F-38
		c) Start, Repeat and End substructures	F-22
		2. Problem with	
		a) Plate with zero B-matrix	F-29
		b) Plate with non-zero B-matrix	F-7

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
DISPLAC	DISPLAC controls the execution BUCLASP,3,0 overlay which computes panel eigen-vector and element relative displacements.		Inspection F-1
DM	DM generates and evaluates the determinant of the retained node on a plate with a non-interior node.	1. a) N_{11} varying	F-11
		b) N_{11} varying with non-trivial biaxial ratio	F-15
		c) N_{22} varying	F-28
		2. Plate with	
		a) Simply supported node	F-2
		b) Clamped node	F-1
		c) Free node	F-1
		d) Sprung node	F-11
DT	DT calculates the determinant of the coefficient matrix for the equilibrium equations.	1. Flate Plate with non-zero B-matrix	F-7
		2. Flate Plate with zero B-matrix	F-29
ERROR	ERROR prints name of routine where error was detected and error number and calls exit.		Inspection F-40
EVALUE	The routine EVALUE extracts the lowest eigenvalue from a general eigen problem of up to order 15 for the GALERKIN method.		F-17

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
FANGLE	For an element the local to global transformation sines and cosines are obtained.	1. Non-curved panel option	F-1
		2. Curved panel option with element in:	
		a) First or second substructure of panel	F-10
		b) Third substructure of panel to last repeat substructure	F-10
		c) End substructure	F-10
FETCHD	From the panel eigenvector fetch the nodal deflection component for an interior node.	1. Node is in row	
		a) Start substructure	F-22
		1) Is part of an element with a node in the repeat substructure (Inter-relationship nodes defined)	F-22
		2) Is not	F-22
		b) Repeat substructure	F-22
		c) End substructure	F-22
FINDIN	a. For the first node in a substructure definition pair find the smallest interior internal node larger than the first node. b. For the last node in a sub-structure definition pair find the largest interior internal node smaller than the last node.		F-22

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
FNLDIS	For a beam or plate element obtain the element displacement vector by fetching the element nodal displacement vector or backsubstituting for reduced out nodal componenents of plate elements. The Wi's are solved for plate elements.	1. Beam element	F-23
		2. Plate element	
		a) left node reduced out	F-28
		b) right node reduced out	F-28
		c) both nodes interior	F-1
FPLATE	FPLATE (1) calculates the P-root normalization factor for the set of P roots for a plate element, (2) puts together the deflection and force matrices for the plate and (3) calculates the stiffness matrix for the plate.	1. Plate element with non-zero B-matrix	F-7
		2. Plate element with zero B-matrix	F-29

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
FPLCOL	FPLCOL generates for one P-value the columns of the deflection and force matrices for the left and right side of a plate element.	1. Curved Plate Element with non-zero B-matrix	
		N_{11} varying	F-31
		2. Curved Plate Element with zero B-matrix	
		N_{11} varying	F-30
		3. Flate Plate Element with non-zero B-matrix	
		N_{11} varying	F-32
		4. Flate Plate Element with zero B-matrix	
		N_{11} varying	F-34
		5. Curved Plate Element with non-zero B-matrix	
		N_{22} varying	F-7
		6. Curved Plate Element with zero B-matrix	
		N_{22} varying	F-37
		7. Flate Plate Element with non-zero B-matrix	
		N_{22} varying	F-29
		8. Flate Plate Element with zero B-matrix	
		N_{22} varying	F-28

ROUTINE	PURPOSE	CONFIGURATIONS	TEST
GAPUPP	GAPUPP uses Galerkin's Method to obtain an approximation to an individual plate's critical load.	1. Flate Plate	
		a) N_{11} varying	F-11
		b) N_{22} varying	F-28
		c) Biaxial ratio on	
		1) First plate element	F-15
		2) Subsequent plate element	F-16
		2. Curved Plate	F-16
IBLKNO	Obtain for an interior, internal node the corresponding row substructure number.	1. Start substructure only	F-1
		2. Start and End substructures only	F-38
		3. Start, Repeat and End substructures	F-8
IGAL	IGAL supplies information as to the length of blank common in each overlay.		Inspection
LCNTRL	LCNTRL finds for an interval of real numbers the buckling load (if it exists) in the interval to a specified tolerance using a bisection technique.	1. No buckling load found	Inspection
		2. Buckling load found	
		3. Double root encountered at a trial load	
		4. Zero determinant encountered at a trial load	

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
LOADING	LOADING controls the computation of the critical load and wave number for the panel.	1. Various wave number search options	
		a) 1	F-37
		b) 2	F-1
		c) 3	F-36
		d) 4	F-39
		2. Upper Bound Input	F-37
		3. Upper Bound Calculated	F-11
		4. Upper Bound Calculation Option only	F-11
		5. Problem with Beams, Flate and Curved Plates	F-40
MATZ	MATZ zeros out a specified substructure of rows and columns of a matrix.		F-1
NEXTC	NEXTC returns next character on table pointer card.	1. Test for end-of-file	F-37
		2. Illegal character	
PAC (A,I,J,B)	PAC will pack the (J-I+1) rightmost bits of the word B into the bit positions I-J of the word A. The remaining bits of A are unchanged.		F-1

ROUTINE	PURPOSE	CHARACTERSITICS	TEST
PLTDEF	PLTDEF reads and processes plate definition data to produce plate lamina extensional, coupling and bending stiffness matrices. PLTDEF produces transformation matrices used in strain and load calculation.	Problem with	
		1. Lamina stress-strain input	
		a) by P-2 card	F-37
		b) by Table	F-37
		2. Engineering constants input	
		a) by P-1 card	F-1
		b) by Table	F-37
		3. Non-zero B-matrix	
		a) have same radius, loads and stiffness (both Flate & Curved)	F-30, F-40
		b) have different radius, loads and stiffness (both Flate & Curved)	F-32, F-33
		4. Zero B-matrix	F-27
PRDMTX	PRDMTX reduces out the effects of a constrained node for a plate element.	1. The element nodal intercoupling matrix is singular	Inspection
		2. The element nodal intercoupling matrix is non singular	F-1
PRINT	PRINT prints a rectangular matrix up to 8 columns at a time and all rows.		F-81

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
PROOT	PROOT calculates the roots of the equilibrium equations for a plate element.	1. Plate element with non-zero B-matrix	F-7
		2. Plate element with zero B-matrix	F-27
		3. Plate element which is repeated	F-27
RDTBLE	Reading from card images (columns 11-80) floating point data in a free-field format with commas and end of physical card as field delimeters. Slash (/) is the logical card delimeter. Limit of fourteen significant digits.	1. Two or more physical cards used	F-37
		2. E format data	and
		3. E format data with 14 significant digits	subroutine
		4. F format data	tests
		5. F format data with 14 significant digits	
		6. Error exits	
		a) end-of-file, missing slash	
		b) illegal data, bad character, too many characters	
		c) table size limit exceeded	
		d) no data input	
RDVLS	Reads pairs of integers in a 2(2X,I3) format from card images and stores non-zero pairs in an array.	1. End of file encountered	F-1
		2. Maximum of receiving array is exceeded	

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
READTR	Read from a binary file a nodal or elemental transformation matrix.	1. Nodal transformation requested	F-1
		2. Elemental transformation requested	F-1
REDUVE	Reduces one vector into another vector.		F-1
RGEN	RGEN generates the elements of the coefficient matrix for the equilibrium equations for the current orthotropic laminated plate element.	1. Curved Plate Element with zero B-matrix N_{11} varying	F-7
		2. Flate Plate with non-zero B-matrix N_{11} varying	F-37
		3. Flate Plate with zero B-matrix N_{11} varying	F-29
		4. Curved Plate with non-zero B-matrix N_{11} varying	F-28
		5. Curved Plate Element with zero B-matrix N_{22} varying	F-31
		6. Flate Plate with non-zero B-matrix N_{22} varying	F-30
		7. Flate Plate with zero B-matrix N_{22} varying	F-32
		8. Curved Plate with non-zero B-matrix N_{22} varying	F-34

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
SBLKDT	SBLKDT computes the determinant of a symmetric matrix which has an overlapping and repeated substructure.	Symmetric matrix with	
		1. Start substructure only	F-1
		2. Start and End substructures only	F-38
		3. Start, 1 Repeat and End substructures	F-8
		4. Start, 2 Repeat and End substructures	F-22
SELIM	SELIM performs a Gaussian reduction on a symmetric matrix.	1. Non-zero Pivot	F-1
		2. Zero Pivot	Inspection
SOLVE	Solves matrix problem $X \cdot A = B$ for X.	1. X^T is non-singular	F-1
		2. X^T is singular	Inspection
STORE	STORE merges a 4x4 element submatrix associated with a node pair into the appropriate substructure of the panel stiffness matrix.	Panel with	
		1. Start substructure only	F-1
		2. Start and End substructures only	F-38
		3. Start, Repeat and End substructures	F-22
STRMOV	Moves characters starting at a position in one array to a different position in another array.	1. Starting array is more than one word	Inspection
		2. Receiving array is more than one word	F-37

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
SYMBND	Linear equation solver for a symmetric band matrix.	1. Zero pivot encountered	Inspection
		2. All new zero pivots	F-1
S0337A	S0337A controls the execution of BUCLASP through its primary overlays, provides central processor time usage information and controls various η/η_{+1} root crossing searches.	1. Multiple data sets	
		2. Data check option only	F-41
		3. Buckling option only	F-36
		4. Buckling and Eigenvector option	F-1
		5. Multiple root searching option	F-35
TBPOINT	TBPOINT reads the table pointer card following P and B cards and constructs an array of pointers.	1. Repeat option left of slash	F-37
		2. Repeat option right of slash	
TRANF	TRANF transforms nodal stiffness matrix from the local axis to the global axis for plate elements with non-interior node.		F-1 F-2 F-3 F-4 F-5 F-6 F-8 F-9
TRANSF	TRANSF transfers specified blocks of rows and columns from one array to another array.		F-1

ROUTINE	PROGRAM	CHARACTERISTICS	TEST
TRANW	Transform plate element deflections in the curved panel from their final global position to their initial untransformed global position.	Element in a curved panel in the	
		a) First or second substructure of panel	F-10
		b) Third substructure to last repeat of panel	F-10
		c) End substructure of panel	F-10
TRAN1	Transforms nodal deflection component from the global axis to the local axis.		F-1 F-2 F-3 F-4 F-5 F-6 F-8 F-9
UNPAC (A,I,J,B)	UNPAC extracts bits I-J from the word A and places the right-adjusted into the word B. The remaining bits of B are set to zero.		Inspection

ROUTINE	PURPOSE
UPPRBD	UPPRBD calculates the upper bound for the critical load.

CONFIGURATIONS	TEST
1. Problems with	
a) beam elements	F-37
b) similar plate with	
1) same boundary condition with same & different widths	F-33 / F-27
2) different boundary condition	F-27
3) same spring stiffness with same & different widths	F-33 / F-38
4) different sprint stiffness	F-38
2. Plate problems with	
a) N_{22} varying	F-28 / F-36
b) N_{11} varying N_{22_I}	
1) Plate element J is affected, First plate element 3 is affected	F-11
2) Plate element J is not affected, First plate element 3 is affected	F-12
3) Plate element J is affected, First plate element 3 is not affected	F-13
4) Plate element J is not affected, First plate element 3 is not affected	F-14
5) Biaxial ratio ≠ 0, plate element J is affected, First plate element is affected	F-15
6) Biaxial ratio ≠ 0, Plate element J is not affected, First plate element is affected	F-16
7) Biaxial ratio ≠ 0, Plate element J is affected, First plate element is not affected	F-17
8) Biaxial ratio ≠ 0, Plate element J is not affected, First plate element is not affected	F-18

ROUTINE	PURPOSE	CHARACTERISTICS	TEST
USERID	Converts user ID's for nodes, plate elements and beam elements to internal ID's and vice versa.	1. Invalid type for ID search 2. Invalid search option 3. User ID not found 4. Internal ID not valid	Inspection F-64
VIPDR	VIPDR produces the inner product of 2 vectors in double precision.		F-1
ZARK	To find N zeros of an arbitrary complex-valued function of a complex variable.		F-1

10.0 PROGRAM VALIDATION

The program, BUCLASP2, was validated by running various data sets such that all major logic paths were tested. The validation is divided into two categories:

a. Functional Tests
b. Inspection

Listed below is the functional tests and their characteristics. Section 9.3 states for each program/subroutine the test(s) used.

10.1 Input Option Functional Test Correlation

Card	Field	Option		Test
1	1	Data Set Title		F-1
2	1	IPC(1) = 0		F-1
		IPC(1) = 1		F-81
	2	IPC(2) = 0		F-1
		IPC(2) = 1		F-82
	3	IPC(3) = 0		F-1
		IPC(3) = 1		F-83
	4	IPC(4) = 0		F-1
		IPC(4) = 1		F-83
	5	IPC(5) = 0		F-1
		IPC(5) = 1		F-84
	6	IPC(6) = 0		F-1
		IPC(6) = 1		F-85
	7	IPC(7) = 0		F-1
		IPC(7) = 1		F-86
	8	IPC(8) = 0		F-1
		IPC(8) = 1		F-87
3	1	JPC(1) = 0		F-1
		JPC(1) = 1		F-41
	2	JPC(2) = 0		F-36
		JPC(2) = 1		F-1
	3	JPC(3) = 0		F-1
		JPC(3) = 1		F-41
	4	JPC(4) = n	$1 \leq n < 100$	F-89
	5	JPC(5) = k	$4 < k \leq 10$	F-37
4	1	Number of Nodes		F-1
	2	Number of Beams		F-41
	3	Number of Flat Plates		F-41
	4	Number of Curved Plates		F-41

10.1 Continued ...

Card	Field	Option	Test
4 Cont ...			
	5	Curved Panel Option	
		= 0	F-1
		= 1	F-10
	6	Curved Panel Angle	F-10
	7	Section Length	F-1
	8	Load or Strain Value	F-19
	9	Biaxial Ratio	F-15
5	1	Load Option	
		= 1	F-11
		= 2	F-28
		= 3	F-19
	2	Wave Number Option	
		= 1	F-37
		= 2	F-1
		= 3	F-36
		= 4	F-39
	3	Loop Start Value	F-1
	4	Loop End Value	F-1
	5	Lower Limit for Root Search	F-35
	6	Upper Limit for Root Search	F-35
	7	Default Number of Subdivision	
		= blank	F-1
		= n	F-37
	8	Lower Bound Load	F-37
	9	Upper Bound Load	F-37
6	1-16	M-list Values	F-36
7	1-14	M-list Values	F-36
T-1	variable	Thickness Table	F-37

10.1 Continued ...

Card	Field	Option	Test
T-2	variable	Material Table	F-37
C	1-9		F-27
E	1-9		F-27
N	1	Letter N	F-2
	2	User Node Number	F-2
	3	Nodal Boundary Condition	
		= blank	F-2
		= 1	F-2
		= 2	F-1
		= 3	F-1
		= 4	F-11
	4	Y-coordinate	F-2
	5	Z-coordinate	F-2
D	1	Letter "D"	F-1
	2	Number of Substructures	F-1
	3-8	Substructure Node Pairs	
		Start Only	F-1
		Start and End Only	F-38
		Start, Repeat and End	F-22
S	1	Letter "S"	F-11
	2	User Node ID	F-11
	3	W Component	F-11
	4	θ Component	F-11
	5	v Component	F-11
	6	u Component	F-11
F	1	Letter "F"	F-22
	2	User Plate ID	F-22

10.1 Continued ...

Card	Field	Option	Test
F (Cont ...)			
	3	OFF1	F-22
	4	OFF2	F-22
	5	OFF3	F-22
	6	OFF4	F-22
P	1	Letter P	F-1
	2	User Plate ID	F-1
	3	Node I	F-1
	4	Node J	F-1
	5	Plate Type	
		= 1 Flat	F-1
		= 2 Curved	F-30
	6	Element Offset	
		= 0 No	F-1
		= 1 Yes	F-22
	7	Number of Laminas	F-1
	8	Input Mode	
		= 0 P-1, or P-2 card	F-1
		= 1 Table	F-37
	9	N_{22} Load Switch	F-38
		= 0 affected	F-38
		= 1 not affected	F-36
	10	Number of Subdivisions	F-37
	11	Type of Material Properties	
		= 0 Engineering Constants	F-37
		= 1 Q matrix	F-37
P-1	1	T	F-1
	2	E_{11}	F-1
	3	E_{22}	F-1
	4	RNUA	F-1
	5	G_{12}	F-1

10.1 Continued ...

Card	Field	Option	Test
P-2	1	T	F-37
	2	Q_{11}	F-37
	3	Q_{12}	F-37
	4	Q_{22}	F-37
	5	Q_{66}	F-37
B	1	Letter "B"	F-23
	2	User Beam ID	F-23
	3	Beam Node	F-23
	4	Type of Beam	
		= 1	F-25
		= 2	F-24
		= 3	F-26
	5	Number of Layers	F-23
	6	Input Mode	
		= 0 B-1, B-2 or B-3 card	F-23
		= 1 By tables	F-39
	7	Beam Angle	F-23
	8	Beam Area	F-23
B-1	1	E-modulus	F-25
	2	G-modulus	F-25
	3	Moment About Local y-axis	F-25
	4	Moment About Local z-axis	F-25
	5	Warping Constant	F-25
	6	Torsion Constant	F-25
	7	Y offset	F-25
	8	Z offset	F-25
B-2	1	Thickness	F-23
	2	E-modulus	F-23
	3	G-modulus	F-23
	4	Beam Width	F-23

10.1 Continued ...

Card	Field	Option	Test
B-3	1	Radius	F-26
	2	E-modulus	F-26
	3	G-modulus	F-26
L	1	Letter "L"	F-1

10.7

10.2 Functional Test Descriptions

Test	Characteristics
F-1	1. Flat Panel at 90° SS - Free
	2. Buckling and eigenvector solution
	3. MØPT = 2
	4. Flat Plates with
	a. left node reduced out
	b. both nodes interior
	c. right node reduced out
	5. Input by P-1 cards
	6. Simply-supported node
F-2	1. Flat Panel at 90° C - Free
	2. Clamped node
	3. Free node
F-3	1. Flat Panel at 0° angle SS - Free
F-4	1. Flat Panel at 0° angle C - Free
F-5	1. Panel at angle (non-orthogonal) SS - Free B.C.
F-6	1. Panel at angle (non-orthogonal) C - Free B.C.
F-7	1. Flat plate with non-zero B matrix
F-8	1. Curved panel at angle (1)
F-9	1. Curved panel at angle (2)
F-10	1. Repeat Block Curved Panel
F-11	1. N_{11} varying
	2. N_{22I} Input

10.2 F-11 Continued ...	3.	First Plate Affected
	4.	J^{th} Plate Affected
	5.	Sprung B.C.
		(J is the critical element for panel upper bound.)
F-12	1.	N_{11} Varying
	2.	N_{22I} Input
	3.	First Plate Affected
	4.	J^{th} Plate Not Affected
F-13	1.	N_{11} Varying
	2.	N_{22I} Input
	3.	First Plate Not AFfected
	4.	J^{th} Plate Affected
F-14	1.	N_{11} Varying
	2.	N_{22I} Input
	3.	First Plate Not Affected
	4.	J^{th} Plate Not Affected
F-15	1.	Biaxial Ratio
	2.	First Plate AFfected
	3.	J^{th} Plate Affected
F-16	1.	Biaxial Ratio
	2.	First Plate Affected
	3.	J^{th} Plate Not Affected
F-17	1.	Biaxial Ratio
	2.	First Plate Not Affected
	3.	J^{th} Plate Affected

10.2 Continued ...

Test	Characteristics
F-18	1. Biaxial Ratio
	2. First Plate Not Affected
	3. J^{th} Plate Not Affected
F-19	1. N_{22} Varying
	2. EPS 11 Input
	3. First Plate Affected
	4. J^{th} Plate Affected
F-20	1. N_{22} Varying
	2. EPS 11 Input
	3. First Plate Not Affected
	4. J^{th} Plate Affected
F-21	1. Mix of Curved and Flat Plates
F-22	1. Offsets on Plates
	2. Block Interrelationship Node Pairs
	3. Plates with Different A, B & D Matrices
F-23	1. Rectangular Beam with 2 Layers
	2. Angle of Beam is Non-Trivial
F-24	1. Rectangular Beam with 1 Lamina
F-25	1. General Beam Element
F-26	1. Circular Beam with 3 Laminas

10.2 Continued ...

Test	Characteristics
F-27	1. Plate with 3 Layers 2. Rectangular Beam with 15 Layers 3. Similar Plates with Different Boundary Conditions 4. Similar Plates with Same Boundary Conditions with Different Widths 5. Non-Neglected Plate Element with Non-Interior Node
F-28	1. Flat Plate with Zero B-Matrix 2. N_{22} Varying 3. Non-Zero N_{11} Side Load Input
F-29	1. Flat Plate with Zero B-Matrix 2. N_{11} Varying
F-30	1. Curved Plate with Non-Zero B-Matrix 2. Non-Zero N_{11} Side Load Input 3. N_{22} Varying
F-31	1. Curved Plate with Non-Zero B-Matrix 2. Non-Zero N_{22} Side Load Input 3. N_{11} Varying
F-32	1. Determinant Always Positive 2. 0/2 Buckling Condition
F-33	1. Curved Elements with Zero B-Matrix and Different Radii 2. Similar Plates with Same Boundary Conditions with Same Widths 3. Similar Plates with Same Boundary Conditions with Same Widths and Same Spring Stiffness

10.2 Continued ...

Test	Characteristics
F-34	1. Curved Plate with Zero B-Matrix, N_{22} Varying
F-35	1. Multiple Root Searching
F-36	1. N_{22} Varying, N_{11} Input Case with Some Unaffected Elements. MØPT = 3 Used and Buckling Only Option Used
F-37	1. Flat Plate with Bij $\neq$ 0 with Input Upper Bound and MØPT = 1. Qij of One Plate Input with P-2 Card, Qij of Another Plate Input with Table and Card. E, ν Input by Table, JPC(5) = 6; Default Subdivisions = 10; One Element Set = 5
F-38	1. Two Identical Plates with Different Spring Stiffnesses at the Same Sprung Sides Going Through the Upper Bound Calculations. Only Start and End Substructures are Used for This Problem.
F-39	1. One Beam is Circular with One Layer, the Other is a General Beam with Offsets. The Circular Beam is Input with Table. MØPT = 4 is Used.
F-40	1. Two Laminated Plates with Same Loads and Radii, But with Different Widths. These Plates are Not Considered Identical From the Stiffness Standpoint.
F-41	1. Too Many Nodes

10.2 Continued ...

Test	Characteristics
F-42	1. Too Many Elements
F-43	1. Too Many Beams
F-44	1. Too Many Plates
F-45	1. Bad Equivalent Node Data 2. Equivalent Nodes with Different Boundary Conditions
F-46	1. Bad Interrelation Node Data
F-47	1. Too Many Values in M-List
F-48	1. No L Card
F-49	1. Non-Element Data Out of Order
F-50	1. Too Many Nodal Spring Stiffnesses
F-51	1. Too Many Plate Offsets
F-52	1. Too Many Interrelationship Node Pairs
F-53	1. Too Many Equivalent Node Pairs
F-54	1. Bad Table Input
F-55	1. Incorrect Number of Nodes Input
F-56	1. Bad Thickness Table
F-57	1. Too Many P Cards
F-58	1. Too Many B Cards Input
F-59	1. Invalid Load Option

10.2 Continued ...

Test	Characteristics
F-60	1. Invalid Wave Number Search Option
F-61	1. Too Many N Cards
F-62	1. Illegal Boundary Condition
F-63	1. Wrong Number of Spring Stiffnesses Input
F-64	1. Bad User ID on Nodal Stiffness Set
F-65	1. Bad User ID in Interrelationship Data
F-66	1. Bad User ID in Equivalent Node Data
F-67	1. Bad User ID in Substructure Definition
F-68	1. Incorrect Number of Substructure Definition Node Pairs Input
F-69	1. Substructure Definition Node Pair Out of Order
F-70	1. Interrelationship Between Blocks Invalid
F-71	1. Invalid Node Used on Plate
F-72	1. Invalid Node on Beam Definition
F-73	1. Incorrect Number of Plates Input
F-74	1. Incorrect Number of Beams Input
F-75	1. Node in Start Substructure with Attachment to Element to Repeat, But Not Part of a Connection Node Pair.

10.14

10.2 Continued ...

Test	Characteristics
F-76	1. Block with No Interior Node
F-77	1. Panel with 2 Substructure, But No End Substructure
F-78	1. Boundary Condition on Beam Node
F-79	1. Beam Node Which is Not Equivalenced
F-80	1. Element with Nodes in Start and End Substructure
F-81	1. IPC(1) = 1
F-82	1. IPC(2) = 1
F-83	1. IPC(3) = 1
F-84	1. IPC(4) = 1
F-85	1. IPC(5) = 1
F-86	1. IPC(6) = 1
F-87	1. IPC(7) = 1
F-88	1. IPC(8) = 1
F-89	1. JPC(4) = $n < 100$ and $n \neq 0$
F-90	1. Duplicate User ID on Nodes 2. Duplicate User ID on Beams 3. Duplicate User ID on Plates

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